NOAA Technical Memorandum NMFS F/NWC-160

Life History, and Harvest Summaries for Selected Invertebrate Species Occurring off the West Coast of North America

Volume 1: Shelled Molluscs

by
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February 1989

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

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LIFE HISTORY AND HARVEST SUMMARIES FOR SELECTED INVERTEBRATE SPECIES OCCURRING OFF THE WEST COAST OF NORTH AMERICA

VOLUME 1: SHELLED MOLLUSCS

by

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February 1989

ABSTRACT

This report comprises synopses of the biology and human utilization of 17 species of abalones, clams, and other bivalves that are found off the west coast of North America. Included in each species synopsis is information on geographic range, habitat requirements, human utilization (commercial, recreational, and subsistence), management, migration and movements, population characteristics, growth and development, food and feeding, biological interactions, and factors influencing populations;, A list of common and scientific names, a gazetteer of place names mentioned in the report, and a glossary of terms follow the synopses.

The following are the species addressed:

Pink abalone, Haliotis corrugata
Black abalone, H. cracherodii
Green abalone, H. fulgens
Pinto abalone, H. kamtschatkana
Red abalone, H. rufescens
White abalone, H. sorensoni
Flat abalone, H. walallensis
Pacific oyster, Crassostrea gigas
Pacific geoduck, Panope abrupta
Pacific littleneck clam, Protothaca staminea
Pacific razor clam, Siligua patula
California jackknife clam, Tagelus californianus
Manila clam, Tapes philippinarum
Pismo clam, Tivela stultorum
Fat gaper or horse clam, Tresus capax
Pacific gaper or horse clam, I. nuttallii
Weathervane scallop, Patinopecten caurinus

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CONTENTS

INTRODUCTION

From 1984 to 1988, members of the National Marine Fisheries Service's (NMFS) Northwest and Alaska Fisheries Center (NWAFC) helped the National Ocean Service's Strategic Assessment Branch develop a data atlas for marine resources off the west coast of North America. Entitled West Coast of North America Coastal and Ocean Zones Strategic Assessment: Data Atlas, the Data Atlas is a graphic and written summary of important characteristics of marine resources in the region. It includes descriptions of how marine resources are utilized by humans and the impact of other human activities. A major component of the Data Atlas is the section on living marine resources, which includes life history summaries and associated maps portraying temporal and spatial distributions of the marine resources at various life stages. This living marine resource section of the Atlas is the principal component that NWAFC scientists developed. Over 100 species of marine mammals, birds, fishes, and invertebrates are addressed.

Although the Data Atlas is a thorough condensation of the salient points for each species, its format restricts the quantity of information that can be presented. Details on geographic distribution, seasonal movements, life history, or human utilization simply could not be incorporated. Consequently, members from the NWAFC's Resource Assessment and Conservation Engineering Division, who compiled the information on fishes and invertebrates for the Data Atlas, decided to publish this Information in a less condensed form. This report represents the initial effort to do so.

The following is a collection of species synopses for the shelled molluscs covered in the Data Atlas. This volume summarizes information on 17 species of abalones, clams, and other bivalves. A second volume will cover cephalopods, crabs, shrimps, and one species of lobster; the third will cover demersal fishes; and the fourth will cover anadromous and pelagic fishes.

PROCEDURES FOLLOWED IN DEVELOPMENT OF SPECIES SYNOPSES

The species in the Data Atlas were selected based on a combination of factors: economic importance, ecological significance, and richness of information. Representatives from a cross section of marine habitats from the intertidal zone down to continental slope depths and out into the open ocean have been selected.

All synopses follow a standard format (Table 1). Among the topics addressed are regional and depth distribution, life history characteristics, human utilization (i.e., commercial, recreational, and subsistence harvests), and resource management. The life history information summarizes historical material from the scientific literature through 1986, although more recent sources are occasionally included. Original sources were preferred; synthesized material was used when other references were not available.

Information on harvest was obtained from three sources: published literature, computer summaries from resource management agencies, and personal communications with resource managers. Harvest descriptions focus on a series of "baseline" years (1981-83) that were established during the initial drafting of the Data Atlas. Historic summaries are also included when appropriate and more recent catch statistics are provided when available. Catch values for U.S. landings are derived from fisheries statistics publications prepared by the NMFS National Fishery Statistics Program and from state or regional management agencies. Values for Canadian harvests are derived from Canada Department of Fisheries and Oceans annual catch statistics documents and have been adjusted to U.S. dollars unless otherwise indicated. Currency exchange rates for, the baseline years are: 1.2000 for 1981, 1.2344 for 1982, and 1.2325 for 1983.

Table 1.--Standard format followed in species synopses.

Common Name, Scientific Name
Other Common Names
Classification
Management
Value
Commercial
Recreational
Subsistence
Ecological
Range
Worldwide
Within Study Area
Life Mode
Habitat
Type
Substrate
Physical/Chemical
Migrations and Movements
Population Characteristics
Reproduction
Mode
Spawning
Fertilization
Reproductive Potential
Egg Size
Embryonic Development
Larval Size Range
Juvenile Size Range
Age and Size of Adults
Release of Young (where appropriate)
Food and Feeding
Trophic Mode
Food Items
Feeding Behavior
Biological Interactions
Predation
Competition
Symbiotic Relationships
Social Interactions
Community Associations and Interactions
Factors Influencing Populations

Some procedures were adopted to condense the text and improve its flow without lessening its content. The references in the synopses are combined into a master list that is numbered sequentially. The number of the reference is cited in the text rather than the author and date. Personal communications are cited in the reference list to eliminate footnotes.

Only common names for life forms are mentioned in the text unless they are unavailable. Common names used for fishes are those recognized by the American Fisheries Society, and common names for invertebrates are those used in extensive publications, such as Abbott et al. (1968), Smith and Carlton (1975), and Morris et al. (1980). A list of these common names and associated scientific nomenclature is presented in Appendix A.

A gazetteer for all place names, geographic features, and marine areas is presented in Appendix B. It includes locations mentioned not only in this volume of species synopses, but in the three subsequent volumes as well. Appendix C is a glossary of scientific terms.

PINK ABALONE, Haliotis corrugata Wood, 1828 (2,119)

(corrugated abalone, rough abalone, yellow abalone (49,69))

CLASSIFICATION

Phylum--Mollusca

Class--Gastropoda

Order--Archaeogastropoda

Family--Haliotidae (2,18)

MANAGEMENT

Because pink abalone is a coastal species, it is not covered by federal fishery management plans in the United States. Harvests are regulated by the California Department of Fish and Game in California and by the Departmenta de Pesca in Mexico (39,49,64,162).

VALUE

Commercial--Pink abalone is commercially valuable because of its excellent taste, but now it is not as abundant as other abalones. Catches in recent years (1981-83) have averaged about 35 metric tons (t), which ranks fourth in volume for all abalones harvested in U.S. waters (12,37,38,40). The annual value to U.S. fishermen for these catches has averaged slightly more than $200,000 (42). Between 1972 and 1976, harvests were more substantial, averaging over 190 t (117,118,138,147,148).

Pink abalone is commercially harvested along the coast of southern California down to central Baja California by divers at depths of 6-55 m (mostly 8-14 m) (49,65). Important fishing areas include waters off Santa Barbara and San Clemente Islands In California, and some areas along the Baja California Norte coast from Santa Rosilia to Tortugas Bay and at Guadalupe,

Cedros, and the Los Coronados Islands (2,49,144). Other less important fishing locations in California are off San Miguel, Santa Cruz, Anacapa, San Nicolas, and the Santa Catalina Islands (2,49). Harvests in California waters are regulated by season and minimum abalone size (6-3/4") (162). Abalone fishing is closed during February and August; the fishery operates during the rest of the year, but more than half of recent harvests (1981-83) were landed during January, April, and May (37,38,40).

Pink abalone meat must be tenderized by pounding before eating. It is sold fresh or frozen in steaks. Trimmings from the steak cutting process are canned (65,148). This is an important commercial abalone species in Mexico where it is canned and exported (65). It is not known how much of Mexico's abalone exports to the United States is composed of this species (from 1981 to 1983, Mexico exported nearly 2,700 t of abalone meats to the United States (128)). Juvenile pink abalone have been successfully cultured and, hence, there is some mariculture potential (2).

Recreational--Pink abalone is an important species in southern California and is taken by scuba divers with pry-irons. Harvests occur from mid-March to mid-January, except along the eastern shore of Santa Catalina Island where they are taken only between April and October (39,65). They are fished along the mainland from Santa Barbara to San Diego (except from Palos Verdes Point to Dana Point) and at Santa Cruz, Anacapa, and Santa Catalina Islands (49,65).

Ecological--Pink abalone is a major consumer of drift kelp in giant kelp beds in southern California and northern Baja California (49).

RANGE

Worldwide--Pink abalone is a warm-temperate (San Diegan), northeastern Pacific species with a range that lies entirely within the region covered in the Data Atlas.

Within Study Area--This species ranges from Point Conception (possibly Monterey), California, to Magdalena Bay, Baja California Sur (2,83,123,144). Pink abalone is also found on the islands off the southern California coast (including Cortez Bank) and off the northern and central Baja California coast (including Guadalupe Island) (2,49). It is most abundant in California at Santa Cruz, Santa Barbara, Santa Catalina, and San Clemente Islands (49,144).

LIFE MODE

Like red abalone eggs, pink abalone eggs are pelagic when spawned but probably sink after fertilization (2). Larvae are pelagic, but they become benthic when the developing shell becomes too heavy (49). Juveniles and adults are benthic (49).

HABITAT

Type--Eggs are probably intertidal-sublittoral, from the lower intertidal zone to 60 m. Larvae are neritic. Juveniles are sublittoral from 6 to 60 m. Adults are intertidal-sublittoral from the lower intertidal zone to 60 m, but are most common at 6-24 m (2,49).

Substrate--Eggs probably occur loosely on rocky bottoms (2,49). Postlarvae and juveniles are found in crevices and under rocks (65). Adults are found on exposed surfaces of rocks (49).

Physical/Chemical--Pink abalone occurs in euhaline waters of temperatures greater than 14°C and probably spawn at 20°C (2,49). Juveniles and adults are found in areas that are both protected from and exposed to wave turbulence (49).

MIGRATIONS AND MOVEMENTS

Pink abalone is one of the least mobile abalone species. Adults may occupy a permanent scar on the rocks for life (2,144); however, some individuals move to new locations in response to food availability or habitat disturbance (144).

POPULATION CHARACTERISTICS

Two subspecies have been described: H. corrugata corrugata occurs from Point Conception, California, to Asuncion Island, (probably to Magdalena Bay) Baja California Sur; H. C. oweni, is found near Guadalupe Island (2,120). In southern California pink abalone hybridizes with several other abalones: most often with red, sometimes with green and flat, and rarely with white and pinto abalone (2).

REPRODUCTION

Mode--Sexual, separate sexes, oviparous (49).

Mating--Reproduction occurs in late winter and from May to September (2,124). Mating is stimulated by rising water temperatures or mechanical stimulation (49,651. During mating, both sexes elevate the shell and twist from side to side, squeezing out gametes from their respiratory pores (49,65). Eggs are pelagic when extruded (49).

Fertilization--External, in the water column (65).

Reproductive Potential--Each female releases 1 million to 2 million eggs per year and may spawn twice annually, in late winter and early summer (2).

Release of Young--Fertilized eggs are found in late winter and early summer to depths of 60 m (2).

GROWTH AND DEVELOPMENT

Egg Size--Undescribed.

Embryonic Development--Indirect and external (2). Like the eggs of red abalone, pink abalone eggs probably develop into free-swimming trochophore larvae within 12 hours of fertilization (2). The larval period lasts 1-3 months (1-2 weeks in water column) and occurs in late winter and in early summer (2,65,124). Larvae pass through a trochophore and veliger stage (49).

Larval Size Range--Undescribed.

Juvenile Size--Undescribed; probably from about 2-40 mm if similar to red abalone (2,124).

Age and Size of Adults--Adults mature at 2-3 years (probably about 40 mm if similar to red abalone). They may live more than 25 years; maximum size is 254 mm (2,49,144). It takes 9 years to reach 150 mm, the minimum size for recreational harvests; 10-11 years to reach commercial size (171 mm or 6-3/4") (34).

FOOD AND FEEDING

Trophic Mode--Herbivore (2).

Food Items--Larvae feed on microscopic plants (65). Juveniles feed initially on benthic diatoms, then on coralline algae, and later on macroalgae (49). Adults feed on drift algae, preferring the giant kelp, sea-oaks, and a red algae (*Plocamium*), and also on certain kinds of brown algae (*Dictyopteris* and *Pachydictyon*) (49).

Feeding Behavior--Pink abalone larvae feed in the water column. Juveniles use their radulae to graze on diatoms and algae that grow on rocks (49). At 1-2 years, juveniles switch from grazing to capturing drift algae. A larger juvenile or adult captures drift algae with its foot (2). Adults are nocturnally active (124).

BIOLOGICAL INTERACTIONS

Predation--Major predators on pink abalone juveniles and adults include sea stars, two-spotted octopus, and man, who is the greatest predator (2,93). California spiny lobsters eat juveniles and bat rays eat adults (144). Other potential predators living within the range of the pink abalone include Pacific rock crab, cabezon, and California sheephead. California moray and lingcod may eat abalone that have been dislodged from their rocks (65,33). Juveniles are cryptically colored and live in cracks and crevices as defense against predation. Adults cling tightly to exposed surfaces of rocks and are armored with a thick shell (2,49).

Competition--Pink abalone probably competes with other abalone species where their ranges overlap. It appears to, at least partially, replace red abalone geographically and occurs in less turbulent water than green abalone (2). It competes with red and purple sea urchins for kelp; both urchin species are more intensive grazers and can damage abalone food supplies (49).

Symbiotic Relationships--Pink abalone are parasitized by gnathostomatid nematodes (49). The shell is covered with encrusting plants and animals (49). Pholadid clams and date mussels burrow into the shell causing the abalone to produce blister pearls on the inner surface of the shell (49). The purple alpheid shrimp lives commensally beneath the shell (49).

Social Interactions--Undescribed.

Community Associations and Interactions--Pink abalone are commonly associated with beds of giant kelp. In some parts of southern California it is being replaced by red abalone (83).

FACTORS INFLUENCING POPULATIONS

Pink abalone populations may be depleted when warm, oligotrophic El Niño waters destroy kelp beds and, hence, their major food source. If sand covers

their rocks they must move, often exposing themselves to predation. During major storms, many are killed by decreased salinities, increased sedimentation, and wave-induced rolling rocks (49). Man is the major predator of pink abalone. Overfishing has depleted legal-sized individuals from the shore to 20 m along the southern California mainland (2). Of all species of abalone, pink abalone has been most severely affected by excessive harvests (124).

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BLACK ABALONE, *Haliotis cracherodii* Leach, 1817 (2)

CLASSIFICATION

Phylum--Mollusca

Class--Gastropoda

Order--Archaeogastropoda

Family--Haliotidae (2,18)

MANAGEMENT

Because black abalone has a coastal distribution, it is not covered by federal fishery management plans in the United States. Harvests are monitored by state agencies in Oregon and California and by the Departmenta de Pesca in Mexico (39,49,66,142,162).

VALUE

Commercial--The flavor of this species is inferior to the flavor of other abalones (124), but since other populations have been depleted (e.g., pink and red abalones), it has become important in commercial harvests (2). By the early 1970s, it was first in volume landed, with the 1973 catches as high as 870 t (117,118,138,147,148). Black abalone remains the most harvested species; however, catches in recent years (1981-83) have averaged only about 234 t per annum (37,38,40). This amount is nearly 40% of the total Canada landings (37,38,40,43,44,45).

Black abalone is commercially fished off California and Mexico in shallow water (less than 6 m) and intertidal areas (2,49); divers use pry-irons to remove the abalone from rocks (16,65,66,157). Only incidental amounts are landed north of the Santa Barbara region (as far north as the Eureka region) (37,38,40,117,118,138,147,148). Other important fishing areas

include: San Miguel, San Nicholas, and San Clemente Islands off southern California (162), the Los Coronados Islands, Cedros Island, and the Baja California coast from Santa Rosalia Bay to Point San Juanico in Mexico (18). Harvests in California waters are regulated by size (5-3/4", minimum) and season. The fishery is closed during February and August; in recent years over half the annual harvests were landed during April-July (37,38,40).

The meat of this species is dark colored and is tenderized by pounding. It is sold in the United States as fresh or frozen steaks and its trimmings are canned (65). Most of the commercial harvest is exported to the Orient (83). In Mexico, it is dried and used as lobster bait or it is canned and exported (49,124).

Recreational--Black abalone is an important species to sport divers in southern California. It is fished from the shore and in shallow water by divers from mid-March to mid-January except along the eastern shore of Santa Catalina Island where it is harvested from April through October (39,65). Black abalone is taken along the mainland from Santa Barbara to San Diego (except from Palos Verdes Point to Dana Point) and at Santa Cruz, Anacapa, and Santa Catalina Islands (49,65).

Ecological--This is the most abundant species of abalone in southern California and one of the most common intertidal herbivores in central California (35,123,144).

RANGE

Worldwide--The species is a temperate (Oregonian-San Diegan), northeastern Pacific species with a range that lies entirely within the region of the Data Atlas.

Within Study Area--Black abalone ranges from Coos Bay, Oregon, to Cabo San Lucas, Baja California Sur, and on Guadalupe Island, Baja California (2,49).

It is common in the area south of central California (157).

LIFE MODE

Eggs are pelagic when spawned but may sink after fertilization (2). Larvae are pelagic, but they become benthic when the developing shell becomes too heavy (49). Juveniles and adults are benthic (65).

HABITAT

Type--Eggs are probably intertidal-shallow sublittoral from tidepools to 6 m (49). Larvae are neritic. Juveniles and adults are found from the intertidal to the sublittoral zone, from the high-tide mark to 6 m (49). This species occurs higher in the intertidal zone than any other abalone (2).

Substrate--The eggs probably occur loosely in tidepools and on shallow subtidal rocky bottoms. Trochophore and veliger larvae occur in the water column (2,49). Postlarvae, juveniles, and adults are found in crevices and under large rocks (2,65).

Physical/Chemical--Black abalone occurs in euhaline waters but because of its intertidal habitat, it is probably tolerant of a wider range of salinities and temperature and of desiccation than most abalones. It probably spawns at temperatures of 20°C, but may spawn at lower temperatures (49). Black abalone is common in surf swept areas (157).

MIGRATIONS AND MOVEMENTS

Adults are sedentary, but move around within the habitat (2,144).

POPULATION CHARACTERISTICS

Two subspecies of black abalone have been described. Haliotis cracherodii cracherodii occurs from Coos Bay, Oregon, to Cabo San Lucas, Baja California Sur, and H. c. californiensis is found on Guadalupe Island off the central coast of Baja California (5). Black abalone do not hybridize with other abalone species (2).

REPRODUCTION

m--Sexual, separate sexes, oviparous (49).

Mating--Spawning occurs from late spring through summer (i.e., April-September) and perhaps also, to a limited extent, in winter (2,124). Mating is stimulated by rising water temperatures or mechanical stimulation (49,65). During mating, both sexes elevate their shells and twist from side to side, squeezing out gametes from their respiratory pores (49,65). The eggs are pelagic when extruded (49). Spawning is more or less synchronous at a given location, but adjacent populations may spawn several weeks apart (2).

Fertilization--External, in the water column (65).

Reproductive Potential--Black abalone spawn twice per year (2). Their fecundity is undescribed.

Release of young--Early life stages are found to depths of 6 m probably from late spring to summer (2,49).

GROWTH AND DEVELOPMENT

Egg Size--Undescribed, probably about 0.2 mm (124).

Embryonic Development--Indirect and external (49). Like the swimming trochopore larvae of red abalone, swimming trochophore larvae of black abalone probably develop within about 12 hours of fertilization (2). The larval period lasts 1-3 months (1-2 weeks in water column) and occurs in winter and

late spring-summer (2,65,124).

Larval Size Range--Undescribed, probably less than 2 mm (124).

Juvenile Size Range--Undescribed, probably 2-40 mm if similar to red abalone (2,124).

Age and Size of Adults--Age and size at maturity are undescribed. Adults live for at least 10 years and reach a maximum size of 203 mm (49,65,124).

FOOD AND FEEDING

(Trophic Mode--Herbivore (2).

Food Items--The larvae feed on microscopic plants (65). Juveniles feed initially on benthic diatoms, then on coralline algae, and later on macroalgae when they reach 10 mm in length (49). Adults feed on diatoms and on drift algae (they prefer feather-boa kelp) and they also eat giant kelp, Pelvetia spp., and red algae (Gigartina canaliculata) (2,49,124).

Feeding Behavior--Larvae feed in the water column (49). Using their radulae juveniles graze on benthic plants on rocks (49,65). Adults catch drift algae with their feet, and they also graze on rocks and on algae on other black abalone shells (2,49). Adults are nocturnally active (124).

BIOLOGICAL INTERACTIONS

Predation--Major predators on juvenile and adult black abalone include large pebble crabs, ocher stars, and two-spotted octopus (2,68,93). Other potential predators living within its range include sun stars, Pacific rock crab, cabezon, California sheephead, and sea otters (65). California moray and lingcod may eat abalone that have been dislodged from their rocks (33,65). Juveniles are cryptically colored and live in cracks and crevices as defense against predation (49). Adults cling tightly to rocks, are armored with a thick shell, and show avoidance reactions to ocher stars (2,49).

Competition--Black abalone probably competes with other abalone species where their ranges overlap. It is replaced subtidally by red abalone in central California and by green abalone in southern California and Baja California (2,35). It occurs higher intertidally than other abalones (2). It also competes with chitons, limpets, black turbans, and red and purple sea urchins (which are more intensive grazers) (35,49).

Symbiotic Relationships--Black abalone shells have fewer encrusting organisms than the shells of other abalones, although black abalone may be encrusted with barnacles and bryozoans (113,157). Intertidal individuals have shells riddled with boring sponges; subtidal individuals have certain piddocks. Boring clams stimulate the formation of blister pearls on the inner surface of the shell (2,113). Purple alpheid shrimp live commensally beneath the shell (49).

Social Interactions--They are usually crowded close together, sometimes stacked 2-3 high, and graze on each others' shells (49).

Community Associations--Juveniles live in depressions with purple sea urchins (35).

FACTORS INFLUENCING POPULATIONS

Black abalone populations may be depleted when warm, oligotrophic El Niño waters destroy kelp beds, their major food source. If sand covers their rocks, they must move, often exposing themselves to predation. During major storms, many are killed by decreased salinities, increased sedimentation, and wave-induced rolling rocks (49). Sea otters greatly reduce local densities of black abalone (144). Humans are a major predator of this species.

GREEN ABALONE, Haliotis fulgens Philippi, 1845 (2)

(blue abalone, southern green abalone, splendid abalone, splendid ear shell (69,124))

CLASSIFICATION

Phylum--Mollusca

Class--Gastropoda

Order--Archaeogastropoda

Family--Haliotidae (2,181

MANAGEMENT

Because green abalone is a coastal species, it is not covered by federal management plans in the United States. Harvests are regulated by the Department of Fish and Game in California and the Departmenta de Pesca in Mexico (39,49,66,161).

VALUE

Commercial--Green abalone is highly valued because of its taste (124). It is not as abundant in U.S. waters as in the past. From 1981 to 1983, it ranked fifth in volume with annual harvests averaging only about 29 t (37,38,40) (harvests during the late 1950s approached 1,000 t per year (161)). Recent harvests have produced an ex-vessel value of slightly less than $200,000 annually (128). It is fished commercially by divers in shallow subtidal waters (3-8 m) (5,16,49,65,157,161).

A species breakdown for abalone harvests in Mexico is not available, although some species-combined values, are available. For 1981-83, nationwide abalone harvests averaged 1,387 t and landings from the region covered in the Data Atlas were a substantial portion of these harvests (e.g., 1,403 t in

1981; 79% of nationwide total) (52,53,54).

Important fishing areas include California waters off the islands of Santa Cruz, Santa Barbara, Santa Catalina and San Clemente, and Mexican coastal regions from Santa Rosilina Bay to Point San Juanico, and off Cedros and the Los Coronados Islands (49).

As with all other abalone, green abalone harvests are regulated by a minimum size limit (7") (161) and fishing seasons. The California abalone fishery is closed during February, and although landings of this species occur throughout the open periods, over half of recent catches have occurred between April and July (37,38,40). Its meat must be tenderized by pounding and is sold in the United States as fresh or frozen steaks. Trimmings from the steaks are canned, frozen, or ground into meal and are exported (65,124).

Recreational--Green abalone is a recreationally important species in California. It is taken with pry-irons from the lower intertidal zone to 24 m from mid-March to mid-January, except along the eastern shore of Santa Catalina Island where it is fished only from April to October (39,65). It is along the mainland from Santa Barbara to San Diego (except from Palos Verdes Point to Dana Point) and at Anacapa, Santa Cruz, Santa Barbara, San Clemente, and Catalina Islands (49,65).

Ecological--The green abalone is the dominant abalone in the shallow subtidal zone on exposed coasts in southern California (2).

RANGE

Worldwide--The green abalone is a warm-temperate (San Diegan) Pacific species; its range lies entirely within the region covered in the Data Atlas.

Within Study Area--The green abalone ranges from Point Conception, California, to Magadalena Bay, Baja California Sur, and near Guadalupe Island (2,49). Highest abundance in California waters apparently occurs off Santa Cruz, Santa

Barbara, San Clemente, and Santa Catalina Islands (112). Earlier reports of occurrences at the Farallon Islands and Monterey Bay are questionable (49).

LIFE MODE

Like red abalone eggs, green abalone eggs are pelagic when spawned but may sink after fertilization (2). Larvae are pelagic, but they become benthic when the developing shell becomes too heavy (49). Juveniles and adults are benthic (65).

HABITAT

u--Green abalone eggs probably occur from the lower intertidal zone to 24 m (49,133). Larvae are neritic. Juveniles and adults occur from the lower intertidal zone to 24 m (49,133); they are most common at 2-3 m and are scarce below 10 m. Their lower limit is set by the availability of-drifting red algae and possibly by temperature (2).

Substrate--Eggs probably occur loosely in tidepools and on shallow subtidal rocky bottoms. Postlarvae, juveniles, and adults occur in deep crevices on rocky bottoms or under rocks, particularly where surfgrass and algal cover are dense (112).

Physical/Chemical--Green abalone occurs in euhaline waters and probably spawn at 20°C (49). Juveniles and adults live on coasts exposed to strong wave action; juveniles are found in very protected areas within this habitat (2).

MIGRATIONS AND MOVEMENTS

Green abalone is generally sedentary but shows some movement. At 1-2 years, green abalone are still cryptic colored and must move to more exposed locations as they grow. Large adults do not move (144).

POPULATION CHARACTERISTICS

Green abalone hybridizes with pink abalone, and, more rarely, with red abalones in southern California (2).

REPRODUCTION

Mode--Sexual, separate sexes, oviparous (49).

Mating--Reproduction occurs from April to August (124). Mating is stimulated by rising water temperatures or mechanical stimulation (49,65). During mating both sexes elevate their shells and twist from side to side, squeezing eggs and sperm from their respiratory pores (49,65). The eggs are pelagic when extruded (49).

Fertilization--External, in the water column (65).

Reproductive Potential--Each female releases 2 million to 3.7 million eggs per year (2). The number of spawnings per year is undescribed.

Release of young--Fertilized eggs are present from early summer to early fall at depths to 24 m (2,49,133).

GROWTH AND DEVELOPMENT

Egg Size--Undescribed; probably 0.2 mm (124).

Embryonic Development--Indirect and external (49). Eggs probably develop into free-swimming trochophore larvae within about 12 hours of fertilization like red abalone eggs (2). The larval period lasts 1-3 months (1-2 weeks in the water column) and occurs from early summer to early fall (2,65,124).

Larval Size Range--Undescribed.

Juvenile Size Range--Undescribed; probably about 2.0 to 40.0 mm, if similar to that of the red abalone (2,124).

Age and Size of Adults--Green abalone probably mature at 2-3 years and may live more than 25 years (144). Maximum size is 254 mm (49).

FOOD AND FEEDING

Trophic Mode--Herbivore (2).

Food Items--Larvae feed on microscopic plants (65). Juveniles feed initially on benthic diatoms, then on coralline algae, and later on macroalgae (49). Adults feed almost exclusively on drift algae, of which they prefer red algae (Gelidium, Gigartina, Plocamium, and Pterocladia), but they also feed on kelps such as feather-boa kelp, giant kelp, and sea-oaks (2,49).

Feeding Behavior--Larvae feed in the water column; juveniles graze on rocks at night, using their radulae (2,49,65). Adults sense drift algae with their mantle tentacles, swing around, and capture it with their feet. They then rasp the algae apart with their radulae (2). They are nocturnally active (124).

BIOLOGICAL INTERACTIONS

Predation--The major predator of green abalone (other than man) is the two-spotted octopus (2,93). Other potential predators of the green abalone include sun stars, California spiny lobster, rock crab, bat rays, California moray, lingcod, cabezon, and California sheephead (2,33,65,144).

For protection from predators, juveniles are cryptically colored; they live deep in crevices and cracks by day, and they are nocturnally active (2,49). They also derive some protection by sharing crevices with California morays, which eat octopus and threaten humans (2).

Competition--Green abalone probably competes with other abalones where their ranges overlap. This species is replaced by black abalone intertidally, pink abalone in deeper water, and red abalone to the north. It lives in more turbulent water and occurs more often in crevices than pink abalone (2).

Symbiotic Relationships--Green abalone are parasitized by gnathostomatid nematodes. It has a shell that is relatively free of encrusting plants and

animals, although boring sponges, piddocks, and date mussels bore into the shell. Piddock and date mussel boring stimulates the formation of blister pearls on the inner shell (2,49,157). Purple alpheid shrimp live commensally under the shell (49).

Social Interactions--Undescribed.

Community Associations and Interactions--Green abalone lives in a zone with abundant drifting red algae and California morays (2).

FACTORS INFLUENCING POPULATIONS

Green abalone populations may be depleted when warm, oligotrophic El Niño waters destroy kelp beds and other algae. If sand covers their rocks they must move, often exposing themselves to predation. During major storms, many are killed by decreased salinities, increased sedimentation, and wave-induced rolling rocks (49). Man is a major predator of this species (2).

PINTO ABALONE, Haliotis kamtschatkana Jonas, 1845 (2,49)

(Japanese abalone, northern abalone, threaded abalone (6,19). Threaded abalone is the common name used extensively in California (144).)

CLASSIFICATION

Phylum--Mollusca

Class--Gastropoda

Order--Archaeogastropoda

Family--Haliotidae (2,18)

MANAGEMENT

Because pinto abalone is a coastal species, it is not covered by federal management plans in the United States. Harvests of pinto abalone are monitored by state agencies In Alaska, Washington, Oregon, and California, by the Canada Department of Fisheries and Oceans in British Columbia, and the Departmenta de Pesca in Mexico (11,39,49,162,181,192).

VALUE

Commercial--Due to abundance declines of other abalones, this species has become more important along the west coast of North America in recent years. Its meat is of moderate quality, but tender and it does not require pounding (124,157). It is fished commercially throughout its range, but the primary fisheries occur in the northern part of British Columbia and in southeast Alaska (11,49). Pinto abalone is the only species harvested in Canada. In recent years (1981-83), it has accounted for one-third of the entire Canada abalone catch, with an average of 145 t landed (10,12,37,38,40,43,44,45,144). U.S. catches of pinto abalone have provided fishermen with annual values of $131,000 to $445,000.

Major fishing areas occur from British Columbia northward and include the outer coasts of Baranof, Dall, and Prince of Wales Islands in southeast Alaska (specifically from southern Sitka Sound to Sandy Bay, Davidson Inlet to Cape Muzon, and Cordova Bay to Cape Chacon); the east coast of the Queen Charlotte Islands; and near the north and south coasts of Vancouver Island in British Columbia (specifically Johnstone Strait, Knight Inlet, and the Strait of Juan De Fuca). Other less important areas are found along most of the remaining British Columbia coast (except for Strait of Georgia region) (12,43,44,45), along central California from Cape San Martin to Avila (2,49), and in Mexico along the northern Baja California coast from Santa Rosilia Bay to Tortugas Bay (volumes in Mexico are unknown; fishing areas inferred from reference 49).

Pinto abalone is taken by hooka or by scuba divers with pry irons or diving knives (to remove individuals from rocks) from the low intertidal zone to 18 m (and deeper In California) (2,29). Harvests are regulated by minimum size limits (3-3/4" in Alaska, 4" in California) and sometimes by two-part fishing seasons. Season openings vary by region. Closures for Alaska (11) and British Columbia (43,44,45) apparently occur on 1 October and 1 March. The California fishery is closed during February and August (162). This species is sold as fresh or frozen steaks, and its trimmings are canned, frozen, or ground into meal (65). Most of the catch from British Columbia is exported to Japan (29).

Recreational--Pinto abalone is picked by sport divers from British Columbia to southern California, although it is most important in British Columbia and Washington (29,181). In the northern end of its range, it is taken intertidally with poles for prying and subtidally by scuba divers. In British Columbia it is picked along the northern coast and also along the western shore of Vancouver Island (29).

Subsistence--Pinto abalone is picked for subsistence fishing or personal use in southeast Alaska (II).

Ecological--Pinto abalone is the major subtidal abalone in the intertidal-shallow zone north of California where it dominates among the herbivores (29)

R A N G E

Worldwide--Pinto abalone is a temperate (Aleutian-Oregonian-San Diegan), northeastern Pacific species with a range entirely within the region cover in the Data Atlas.

Within Study Area--It ranges from Cross Sound in southeast Alaska to Tortugas Bay, Baja California Sur (19,65). It does not occur around Japan and probably does not occur around Unalaska Island, though both localities are mentioned in earlier reports (49,123). A small commercial catch, however, was reported north of Cross Sound (between Cape Spencer and Cape Fairweather) in 1978-79 (105), but it cannot be verified.

LIFE MODE

Eggs are pelagic when spawned but may sink after fertilization, like eggs of red abalone (2,49). Larvae are pelagic, but they become benthic when the developing shell becomes too heavy (65). Juveniles and adults are benthic (65) .

HABITAT

Type--Eggs probably occur from the lower intertidal zone to 60 m (19). Trochophore and veliger larvae are neritic; pinto abalone at later life stages occur from the lower intertidal zone to 60 m (19). Off Alaska and British Columbia it is found from the lower intertidal zone to 9 m (mostly at 3-7 m), while off southern California it is most common at 10-30 m (4,49,124,133,155).

Substrate--Eggs probably occur loosely in tidepools and on shallow subtidal rocky bottoms. Postlarvae and juveniles occur in crevices and beneath rocks (65). Adults occur on surfaces of black rocks; they are not found in crevices (4,49).

Physical/Chemical--Pinto abalone occurs in cool, euhaline waters along exposed coasts that may be protected from wave turbulence. It is absent from quiet waters (29).

MIGRATIONS AND MOVEMENTS

Pinto abalone moves less than 15 m per year (155).

POPULATION CHARACTERISTICS

Two subspecies have been described: northern abalone (H. kamschatkana kamschatkana) is found from Cross Sound, Alaska, to San Diego, California; threaded abalone (H. k. assimilis) occurs from Diablo Cove, California, to Tortugas Bay, Baja California Sur (35,65,120,124). Both subspecies hybridize with red abalone, and H. k. assimilis also hybridizes with pink, white, and flat abalone (2,124). Pinto abalone occurs at average densities of 2.4 per m^2 in its preferred habitat in British Columbia (range: 0.9-5.3 per m^2) (29).

REPRODUCTION

Mode--Sexual, separate sexes, oviparous (49).

Mating--Reproduction occurs from April to August (124). Mating is stimulated by rising water temperatures or mechanical stimulation (49,65). During mating, both sexes elevate their shells and twist from side to side, squeezing out gametes from their respiratory pores (49,65). The eggs are pelagic (49).

Fertilization--External, in water column (65).

Reproductive Potential--Undescribed.

Release of Young--Larvae are probably present from April to August in the intertidal zone to 60 m (19).

GROWTH AND DEVELOPMENT

Egg Size--Undescribed; probably about 0.2 mm (124).

Embryonic Development--Indirect and external (49). Eggs probably develop into free-swimming trochophore larvae within about 12 hours after fertilization (2). The larval period lasts 1-3 months (1-2 weeks spent in the water column) and occurs from spring to fall (2,65,124).

Larval Size Range--Undescribed; probably less than 2 mm (124).

Juvenile Size Range--2-50 mm (124,155).

Age and Size of Adults--Pinto abalone matures at 3 years and at 50 mm (155). It lives 15 years and reaches 152 mm (29,155).

FOOD AND FEEDING

Trophic Mode--Herbivore (107).

Food Items--Larvae feed on microscopic plants (65). Juveniles feed initially on benthic diatoms, then on coralline algae, and later on macroalgae (49). Adults feed on drift algae (primarily giant, bull, and Laminaria kelp), and also graze on diatoms and coralline algae (29,49).

Feeding Behavior--Pinto abalone larvae feed in the water column, and juveniles graze on rocks using their radulae (49,65). Adults probably capture drift algae with their feet (29). Both juveniles and adults are probably nocturnally active (124).

BIOLOGICAL INTERACTIONS

Predation--Octopus and sunflower stars are the major natural predators of pinto abalone (29). Juveniles may also be eaten by certain polychaetes,

whelks, crabs, stars, and fishes; adults by Pacific rock crab, California moray, lingcod, cabezon, California sheephead, and sea otters (29,33,65). Juveniles are cryptically colored and hide under rocks as a defense against predation (29,49). Adults cling tightly to rocks and move at 25 cm per minute to avoid sunflower stars (19).

Competition--Pinto abalone probably compete with other abalones where their ranges overlap. They are replaced intertidally by black abalone to the south. They compete for algae with red and purple sea urchins, both of which are better grazers (49).

Symbiotic Relationships--The shell is encrusted with plants, invertebrates, molluscs, and, in surf areas, with coralline algae (29,49). Boring sponges and pholadid clams drill into the shell and weaken it (29,113). Polynoid polychaetes (Arctonoe vittata) and purple alpheid shrimp live commensally under the shell (29,49).

Social Interactions--It occurs gregariously with members of its own species (157).

Community Associations--Postlarvae settle to the bottom where coralline algae is found (29). Juveniles live in bull kelp beds and in depressions under tests of red sea urchin (29,35). Adults are most abundant in Pterygophora kelp beds, as well as in beds of bull, giant, and Laminaria kelp (29).

FACTORS INFLUENCING POPULATIONS

Pinto abalone populations may be depleted in the south when warm, oligotrophic El Niño waters destroy kelp beds and other algae. If sand covers their rocks they must move, often exposing themselves to predation. During major storms, many are killed by freshwater flooding, increased sedimentation, and wave-induced rolling rocks (29,49). Harvesting by man, particularly in British Columbia, may deplete populations in the future (29); pre-1980

harvests in southeast Alaska also caused an apparent substantial reduction in the resource (105). Sea otters have also reduced pinto abalone populations in central California (144) and possibly southeast Alaska (105).

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RED ABALONE, *Haliotis rufescens* Swainson, 1822 (2)

CLASSIFICATION

Phylum--Mollusca

Class--Gastropoda

Order--Archaeogastropoda

Family--Haliotidae (2,18)

MANAGEMENT

Because red abalone is a coastal species, it is not covered by federal fishery management plans. Harvests are regulated by state agencies in Oregon and California and by the Departmenta de Pesca in Mexico (39,49,142,162).

VALUE

Commercial--This is the preferred abalone species in the California commercial fishery because of its taste and size (144). It has been harvested since the mid-19th century (49) and remains a mainstay of the abalone fishery even though recent harvests are but small fractions of earlier harvests (e.g., 1981-83 averaged 360 t (37,38,40); 1951-70 averaged 1,950 t (49)). Harvests in recent years rank second in volume to black abalone (34% of total California catch, 26% of total Canada catch, 1981-83) but are by far the highest value to fishermen, producing over $880,000 per year from 1981 to 1983 [Authors note: Harvests for 1984 produced even higher volumes--$1.2 million for 136 t.] (128). Ex-vessel price per pound is slightly less than the ex-vessel price for other species (white, green, and pink abalones) but, because of their large size, the price per dozen for red abalone (common unit of sale) is as high as $150 (128).

This valuable species is fished commercially from the coast of northern California to central Baja California, but important fishing areas only occur off the Los Coronados Islands, Baja California Norte, and the coast of California in the following regions: Farallon Islands, Halfmoon Bay, Point Buchon, Point Arguello, San Miguel, Santa Rosa Island, San Nicolas Island, and near San Diego (49,144,162). The coast from Point Lobos to Cayucos, California, is no longer fished due to reduced populations resulting from sea otter foraging (144). Small amounts are taken off Baja California, between Santa Rosilia and Tortugas Bays (49).

The fishery is regulated by a minimum size (7-3/4") and season (California closures occur in February and August (162)). It is harvested by divers with pry-irons at depths of 6-55 m (mostly 8-24 m) (16,65,162). Sizable amounts are taken during most of the open season, but months with highest landings (11-14% of 1981-83 annual catches) are January, April, May, July, and September (37,38,40). Its meat is highly valued (up to $4.21 per pound in 1984) and sold as fresh or frozen steaks; the trimmings are canned, frozen, or ground into meal (65,124). Mariculture has been introduced along the central California coast to raise juveniles that can be transplanted into areas where natural populations have been depleted (83,124).

Recreational--Red abalone is picked recreationally from Oregon to San Diego, California (49). It is most important from Oregon to Pismo Beach, California, but some are taken between Santa Barbara and San Diego and around San Miguel, Santa Rosa, and Santa Barbara Is-lands (49). It is taken by free divers and shore-pickers (at low tide) north of Yankee Point and also by scuba divers south of there (144). Recreational pickers (using pry-irons) harvest them from April to November north of Yankee Point and mid-March to mid-January south of there (39,65). The sport catch approximately equalled the commercial catch in 1971 (65). The sport catch along northern California was estimated

at over 907 t in 1985 (144).

Ecological--Red abalone is the largest species of abalone in the world; it dominates the subtidal zone from southern Oregon to California (49).

RANGE

Worldwide--Red abalone is a temperate (Montereyan-San Diegan), Pacific species with a range that lies entirely within the region covered by the Data Atlas.

Within Study Area--It ranges from Sunset Bay, Oregon, to Tortugas Bay, Baja California Sur (2). Attempts have been made to introduce it north of Newport, Oregon, and in the Strait of Juan de Fuca, Washington (49,157). It is most abundant from Mendocino County to Point Conception, California (124,157). It occurs widely in southern California on the mainland from Point Conception to Santa Barbara, along the Palos Verdes Peninsula, La Jolla, Point Loma, and around San Miguel, Santa Rosa, Santa Cruz, Santa Barbara, and San Nicolas Islands (144). Along Baja California it is present only in upwelling areas (144).

LIFE MODE

Red abalone eggs are pelagic when spawned but are demersal after fertilization (2). The larvae are pelagic until the developing shell becomes too heavy and then they become benthic. Juveniles and adults are benthic (65).

HABITAT

Type--Red abalone eggs probably occur from the lower intertidal zone to 180 m (2). Trochophore and veliger larvae are neritic; postlarvae, juveniles, and adults occur in intertidal and sublittoral zones, ranging from the high tide mark to 180 m (2,49). In northern California they are most abundant at 3-6 m, in central California at 6-17 m, and in southern California at depths greater

than 15 m (2,49).

Substrate--Eggs probably occur loosely in tidepools and on subtidal, rocky bottoms. Trochophore and veliger larvae occur in the water column (49,124). Postlarvae and juveniles occur in crevices and beneath rocks; adults occur on rocky bottoms (49,65).

Physical/Chemical--Red abalone occur in euhaline waters. Temperatures of 15°C are optimal for spawning. Larvae survive well at 10-12°C, and juveniles survive at 10-18°C (178). Adults grow optimally at 15-18°C (124). They require active surf and occur on exposed promontories and headlands (49).

MIGRATIONS AND MOVEMENTS

Red abalone are sedentary and occupy scars on rocks (2); however, considerable movement and shuffling may take place as individuals relocate to occupy more suitable scars (144).

POPULATION CHARACTERISTICS

This species hybridizes with white abalone, occasionally with pink and pinto abalones, and rarely with flat and green abalones (2).

REPRODUCTION

Mode--Sexual, separate sexes, oviparous (49).

Mating--Red abalone mate throughout the year but do not mate at the northern limit of their range at Cape Arago, Oregon (2,124,157). Mating is stimulated by rising water temperatures, mechanical stimulation, exposure to live sperm, or exposure at high tide (2,49,65). During mating, both sexes elevate their shells and twist from side to side, squeezing out gametes from their respiratory pores (49,65). The eggs are pelagic when extruded (49).

Fertilization--External, in the water column (65).

Reproductive Potential--Fecundity ranges from 100,000 eggs for small females to 12.6 million eggs for females at 20 cm (2,157). The number of spawnings per year by an individual is undescribed.

Release of young--Fertilized eggs are present throughout the year and occur from the lower intertidal zone to 180 m.

GROWTH AND DEVELOPMENT

Egg Size--Undescribed; probably about 0.2 mm (124).

Embryonic Development--Indirect and external (49). Free-swimming trochophore larvae develop in about 12 hours after fertilization (2). The pelagic larval period lasts 5 days at 15°C and 14 days at 10°C (2). The overall larval period (pelagic and benthic phases) lasts for 1-3 months and occurs throughout the year (124).

Larval Size Range--Undescribed; likely between 0.2 mm and 2 mm (124).

Juvenile Size Range--2 mm to 40-84 mm, possibly to 102 mm (49,124).

Age and Size of Adults--Red abalone mature at 2-3 years (49,124,144); males at a size of 47-84 mm and females at 40-41 mm (2,70). Adults live longer than 20 years and grow to 305 mm.

FOOD AND FEEDING

Trophic Mode--Herbivore (157)

Food Items--Larvae feed on microscopic plants (65). Juveniles feed initially on benthic diatoms, and then on coralline algae, and at 25 mm they switch to macroalgae (49). Adults feed exclusively on drift algae, primarily bull kelp north of Point Conception and giant kelp south of there (49). Other food items include kelps such as Alaria, Pelagophycus, Postelsia, sea lettuce, and red algae (49,65,70,157).

Feeding Behavior--Larvae feed in the water column; juveniles feed on the rocks using their radulae (49). Adults capture drift algae by clinging to a rock with the posterior part of the foot and extending the epipodal tentacles to detect drift algae. When algae is detected, the sides of the foot fold and grasp it. The algae is then pulled to the head and eaten. Adults also climb up to the stipes of bull, giant, and palm kelp (2,49). [Authors' note: this last observation contradicts an earlier statement indicating that red abalone are sedentary and occupy a permanent scar on rocks.] Adult red abalone are nocturnally active (124).

BIOLOGICAL INTERACTIONS

Predation--Predators include Nuttall's hornmouth (a muricid snail), Kellet's whelk, two-spotted octopus, California spiny lobster, sheep crab Pacific rock crab, asteroid seastars (Astrometis, Pisaster, Pycnopodia), bat rays, California moray, Cabezon, California sheephead, and sea otters (2,91,93,178). Juveniles avoid predation with cryptic coloring and by living in crevices and cracks (49). Adults cling tightly to rocks and retreat from asteroid seastars (2,49).

Competition--Red abalone competes with other abalone where their ranges overlap. It replaces black abalone subtidally in central California and is replaced by white, pink, and green abalones in southern California (35,49). Red abalone competes with red and purple sea urchins, both of which are better grazers (49).

Symbiotic Relationships--Encrusting plants, hydroids, and bryozoans grow on the shell (157). Boring sponges and pholadid clams burrow into the shell, reducing strength and causing blister pearls (2). Bloodsucking pyramidellid snails are ectoparasitic, and purple alpheid shrimp are commensal under the shell (49). Juveniles live in depressions under red sea urchins (35).

Social Interactions--It occurs gregariously with members of its species (157).

Community Associations and Interactions--Red abalone occurs primarily in bull kelp beds (49).

FACTORS INFLUENCING POPULATIONS

Red abalone probably experiences the greatest mortality during the planktonic larval stage (2). Populations may be depleted when warm, oligotrophic El Niño waters destroy kelp beds and other algae. If sand covers their rocks, they must move, often exposing themselves to predation. During major storms, many are killed by decreased salinities, increased sedimentation, and wave-induced rolling rocks (49). Sea otters prey heavily on red abalone along central California; harvests by humans have depleted stocks in recent years (2,157).

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WHITE ABALONE, Haliotis sorensoni Bartsch, 1940

(Chinese abalone (124))

CLASSIFICATION

Phylum--Mollusca

Class--Gastropoda

Order--Archaeogastropoda

Family--Haliotidae (2,18)

MANAGEMENT

Because white abalone is a coastal species, it is not covered by federal fishery management plans. Harvests are regulated by the California Department of Fish and Game in California and the Departmenta de Pesca in Mexico (39,49,66,162).

VALUE

Commercial--This species has meat that is white, fairly tender, and excellent tasting (4,124); it is one of the preferred California abalone species (along with pink abalone and behind red abalone). The meat must be tenderized by pounding. It is sold in the United States as fresh or frozen steaks. Trimmings from the steaking process are canned (65,124). White abalone often brings a lower price due to a high incidence of nematode cysts in the meat (144).

Unfortunately, white abalone is found deeper than most other species (124) and is not very abundant, especially in recent years. Harvests from 1981 to 1983 averaged only 215 kg annually (value $1,400), ranking it a distant sixth in volume for harvests of abalone in U.S. waters (37,38,40). Earlier catches, however, were more substantial; over 220 t were taken

annually during the early 1970s (128). It is fished commercially from southern California to northern Baja California at depths of 24-65 m (49,144). Important harvest areas include areas off Santa Cruz, Santa Barbara, Santa Catalina, and San Clemente Islands and Cortez Bank in California and off the Los Coronados Islands in Mexico (49,144). As with all other abalones, the harvest is regulated by a minimum size limit (6 1/4") and fishing seasons. The California fishery is closed during February and August (162).

Recreational--White abalone is picked in southern California by scuba divers from mid-March to mid-January except along the eastern shore of Santa Catalina Island where it is taken from April to October (39,65). It is picked along the mainland from Point Dume to San Diego (except from Palos Verdes Point to Dana Point) and at Santa Cruz, Anacapa, and Santa Catalina Islands (49,65).

Ecological--White abalone is a major consumer of drift kelp on the outer edge of kelp beds in southern California and northern Baja California (49).

RANGE

Worldwide--White abalone is a warm-temperate (San Diegan), northeastern Pacific species with a range that lies entirely within the region covered by the Data Atlas.

Within Study Area--It ranges from Point Conception, California, to Asuncion Island, Baja California Sur (119). It is rare on the mainland except near the northern and southern extremes of the range (124).

LIFE MODE

White abalone eggs are probably similar to those of red abalone: they are pelagic when spawned and sink after fertilization (2). The larvae are pelagic but they become benthic when the developing shell becomes too heavy. Juveniles and adults are benthic (2).

HABITAT

Type--Eggs, juveniles, and adults are sublittoral. They occur at 4-65 m and are most abundant at depths of 24-30 m (49).

Substrate--White abalone eggs probably occur loosely on rocky bottoms, whereas trochophore and veliger larvae occur in the water column (2,49). Postlarvae and juveniles are probably found in crevices and under rocks (65). Adults occur on rocky bottoms (49).

Physical/Chemical--White abalone lives in euhaline waters 10-14°C, although larvae may survive at higher temperatures (124). Juveniles and adults are probably not tolerant of wave turbulence.

MIGRATIONS AND MOVEMENTS

Adults probably occupy a scar on the rocks as do other abalone species (2).

POPULATION CHARACTERISTICS

White abalone hybridizes most frequently with red abalone, but also with pink, pinto, and flat abalones (124).

REPRODUCTION

Mode--Sexual, separate sexes, oviparous (49).

Mating--White abalone mate in the summer (4). This is probably stimulated by rising water temperatures. During mating both sexes elevate their shells and twist from side to side to squeeze out gametes from their respiratory pores (65,118).

Fertilization--External, in the water column (65).

Reproductive Potential--Undescribed.

Release of Young--Fertilized eggs are found during spring and summer at depths of 4-46 m (4,49).

GROWTH AND DEVELOPMENT

Egg Size--Probably about 0.2 mm (124).

Embryonic Development--Indirect and external (49). The fertilized eggs develop into trochophore larvae in 24-36 hours at 10-14°C (124). The larval period lasts 1-2 weeks and can occur during a 1- to 3-month period in the spring and summer (4,65,124). Larvae pass through trochophore, veliger, and postlarval stages (48).

Larval Size Range--Probably less than 2 mm (124).

Juvenile Size Range--Undescribed.

Age and Size of Adults--Age and size at maturity are undescribed. Adults reach a length of 25 cm; maximum age is unknown (48).

FOOD AND FEEDING

Trophic Mode--Herbivore (48).

Food Items--The larvae feed on microscopic plants (63). Juveniles feed initially on benthic diatoms, then coralline algae, and later on macroalgae (48). Adults feed on drift algae, primarily elk kelp (48).

Feeding Behavior--White abalone larvae feed in the water column. Juveniles use their radulae to graze on diatoms and algae that grow on the rocks (48). Adults capture drift algae with their feet, but if none is available, they may graze on attached algae. Adults are nocturnally active (124).

BIOLOGICAL INTERACTIONS

Predation--White abalone is probably eaten by sea stars, octopus, California spiny lobster, rock crab, bat rays, cabezon, and California sheephead (49,48,141). Adults cling tightly to exposed surfaces of rock and are armored with a thick shell for protection (2,49).

Competition--White abalone probably competes with other abalones, particularly pink and red abalones, where their ranges overlap. It may also compete with

red and purple sea urchins (49).

Symbiotic Relationships--Pholadid clams and date mussels burrow into the shell causing the abalone to produce blister pearls on the inner surface of the shell. The shell is covered with a variety of encrusting plants and animals. Purple alpheid shrimp live commensally beneath the shell (49).

Social Interactions--Undescribed.

Community Associations--White abalone is associated with kelps such as Agarum fimbriatum and elk kelp (49,144).

FACTORS INFLUENCING POPULATIONS

White abalone populations may be depleted when warm, oligotrophic El Niño waters destroy kelp beds and, hence, their major food source. During major storms many abalone may be killed from increased sedimentation (49). Because it is a deepwater species, white abalone may be less exploited by man than other abalone species (124).

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FLAT ABALONE, Haliotis walallensis Stearns, 1899 (49)

(northern green abalone (69))

CLASSIFICATION

Phylum--Mollusca

Class--Gastropoda

Order--Archaeogastropoda

Family--Haliotidae (2,18)

MANAGEMENT

Because flat abalone is a coastal species, it is not covered by federal fishery management plans. Harvests are monitored by the Oregon Department of Fish and Wildlife and the California Department of Fish and Game (39,142,162).

VALUE

Commercial--Although flat abalone has a good flavor, it is not an abundant species and, hence, it does not support a commercial fishery (124). Since 1972, a total of only 10 kg has been identified as this species in abalone landings (128).

Recreational--Small numbers of this species are taken by sport divers in northern California and Oregon, but it is not an important recreational species.

Ecological--Flat abalone is an important subtidal herbivore off the Oregon and northern California coasts (124).

RANGE

Worldwide --Flat abalone is a boreal, eastern Pacific (Oregonian) species with a range lying entirely within the study area.

Within Study Area--It ranges from British Columbia to La Jolla, California (49). Flat abalone is not common north of Oregon or south of Carmel, California (49,107).

LIFE MODE

Flat abalone eggs are probably similar to eggs of red abalone: they are pelagic when spawned but sink after fertilization (2). The larvae are pelagic, but become benthic when the developing shell becomes too heavy. Juveniles and adults are benthic (49).

HABITAT

Type--Eggs, juveniles, and adults are primarily sublittoral, occurring from the intertidal zone to 27 m (4). The larvae are neritic (49).

Substrate--The eggs probably occur loosely on rocky bottoms, whereas trochophore and veliger larvae occur in the water column (2,49). Postlarvae and juveniles are probably found in crevices and under rocks (65).

Physical/Chemical--Flat abalone live in cool, euhaline waters 10-14°C (56,96).

MIGRATIONS AND MOVEMENTS

Like the adults of other abalone species, adult flat abalone are sedentary and tend to occupy scars on the rocks (2,144).

POPULATION CHARACTERISTICS

Flat abalone hybridize with pink, pinto, red, and white abalone (124).

REPRODUCTION

Mode--Sexual, separate sexes, oviparous (49).

Mating--Flat abalone mate in spring and summer (4). Mating is probably stimulated by rising water temperatures or mechanical stimulation (49,65). During mating, both sexes elevate their shells and twist from side to side, squeezing out eggs and sperm from their respiratory pores (49,65).

Fertilization--External, in the water column (65).

Reproductive Potential--The fecundity and spawning frequency of flat abalone have not been described.

Release of Young--Fertilized eggs are present in spring and summer at depths to 27 m (4).

GROWTH AND DEVELOPMENT

Egg Size--Probably about 0.2 mm (124).

Embryonic Development--Indirect and external (49). The eggs probably develop into free-swimming trochophore larvae in 1/2 to 3 days after fertilization (69,124). The larval period probably lasts about 10 days (4).

Larval Size Range--Undescribed. Probably less than 0.2 mm (124).

Juvenile Size Range--Undescribed.

Age and Size of Adults--The age and size at maturity are undescribed. Adults reach 18 cm in length but their maximum age is unknown (124).

FOOD AND FEEDING

Trophic Mode--Herbivore (49).

Food Items--The larvae feed on microscopic plants (65). Juveniles and adults eat diatoms and coralline algae (49).

Feeding Behavior--The larvae feed in the water column. Juveniles and adults graze on algae attached to the rocks using their radulae (49). Adults are probably nocturnally active (124).

BIOLOGICAL INTERACTIONS

Predation--Flat abalone are eaten by cabezon (49). Other predators may include octopus, sea stars, crabs, and sea otters (49). Juveniles probably hide in crevices, whereas adults are protected from predation by clinging tightly to the rocks and by their hard shells (2,49).

Competition--Flat abalone probably competes with other abalones (particularly pinto abalone) in areas where their ranges overlap (49). It may also compete with red and purple sea urchins, which often damage abalone food resources with their intensive grazing (49).

Symbiotic Relationships--Pholadid clams and date mussels burrow into the shell causing the abalone to produce blister pearls on the inner surface of the shell. The shell is covered with a variety of encrusting plants and animals. Purple alpheid shrimp live commensally beneath the shell (49).

Social Interactions--Undescribed.

Community Associations and Interactions--Undescribed.

FACTORS INFLUENCING POPULATIONS

Flat abalone populations may be depleted during strong El Niño years when warm, oligotrophic waters destroy algae beds. If sand covers their rocks they must move, often exposing themselves to predation. During major storms, many are killed by freshwater flooding, increased sedimentation, and wave-induced rolling of rocks (49). Human activities probably have a minor effect on the population.

PACIFIC OYSTER, Crassostrea gigas (Thunberg, 1793) (23)

(Japanese oyster, Miyagi oyster, giant oyster, immigrant oyster (61,154,157))

CLASSIFICATION

Phylum--Mollusca

Class--Bivalvia

Order--Pterioida

Family--Ostreidae (18,23)

MANAGEMENT

Pacific oyster is an estuarine species that is mostly cultured rather than harvested from wild stocks. Most beds are privately owned and harvests are monitored by state fishery agencies in Alaska, Washington, Oregon, and California and by the Fisheries Branch of the Ministry of Agriculture and Fisheries in the provi nce of British Columbia. Harvests are also monitored by state health agencies (150,154,181).

VALUE

Commercial--This highly valued commercial species is cultured in many regions of the world including Australia, Japan, Hawaii, Palau, southwest Europe, the Pacific coast of North America (86,109,121,154), and possibly many other regions (see RANGE). Originally introduced from Japan, the Pacific oyster has been cultured along the west coast of North America since the early 1900s (20,154). Harvest areas have ranged from southeast Alaska to northern Baja California, but current production is centered in the waters of Washington and southwestern British Columbia. In recent years (1981-83), annual harvests of this species along the coast have averaged about 4,956 t: beds in Washington account for 50% of this total, British Columbia for 37%, California for 11%,

and Oregon for the remaining 2%. Harvests from the United States have an average annual value to oystermen of over $6.7 million. In recent years, Canadian harvests have averaged nearly (CN) $1.2 million (32,48,58,1101 111, 131,150,162,185).

Important harvest areas for Pacific oysters include British Columbia waters of the northern Strait of Georgia, Barkley Sound, and Clayoquot Sound (28), and Washington waters of Puget Sound (especially Totten and Case Inlets in the southern part of the sound) and the outer coast areas of Willapa Bay and Grays Harbor (185).

This species is cultivated on "oyster farms" in protected coastal estuaries. Except for significant developments in sales of single whole oysters for the half-shell market in Washington, Oregon, and British Columbia (28,150), most oysters are shucked and sold fresh or fresh frozen, but some are breaded and frozen or smoked and canned (33,65). The pearls of Pacific oyster are not nacreous, making them of little value (4). The food quality of oysters is substantially reduced for some time after spawning. To combat this seasonal product quality problem, a few companies in Washington and California are marketing a nonreproducing oyster. This condition is induced by chemically treating the eggs shortly after fertilization to inhibit the splitting of the second polar body and introducing the extra or triploid set of chromosomes. These triploidy oysters are hoped to be of greater market value because of increased meat weight and longer periods of harvestability (46).

Recreational--Although Pacificoyster is mostly cultivated privately, wild beds do occur in areas of British Columbia and Washington. Recreational harvests occur from Pendrell Sound, British Columbia, to Puget Sound, Washington. In Puget Sound it is taken from September to July and from the intersubtidal region to depths of less than 0.6 m (181).

Ecological--The introduction of this species into North American waters has also resulted in the introduction of associated forms that have become competitors or predators of native species and pests in mariculture. These associated species include sponges, cnidarians, polychaeates, molluscs, crustaceans, and bryozoans (168).

RANGE

Worldwide--The Pacific oyster is a temperate species that is presently found in the Southwest Pacific (southern Australia to New Zealand), in the North Pacific at Hawaii, Palau, from coastal China to the southern Kurile Islands, and from southeast Alaska to northern Mexico (86,97,109,121,123,154,159,191). One source believes the Portuguese oyster (C. angulatus) to be the same species (range includes Portugal, England, and southwest Europe) (121); however, others consider this incorrect (28).

Within Study Area--The Pacific oyster is a part of mariculture endeavors from near Ketchikan, Alaska, to San Quintin Bay, Baja California (23,97). Naturally reproducing populations occur from Pendrell Sound, British Columbia, to Tomales Bay, California (154,169). Because of pollution, this species is not present now in several areas of California (Bodega Bay, Bolinas Lagoon, San Francisco Bay, and Elkhorn Slough) (65).

LIFE MODE

Eggs and early stages of larvae are pelagic. Later larval stages (spat) are sedentary. Juveniles and adults are sessile-benthic (154).

HABITAT

Type--Eggs and larvae are neritic and occur in the upper 4 m of the water column (154). Juveniles and adults are found in bays and estuaries from the

lower intertidal zone out to depths of 7 m (84,159).

Substrate--Late-stage larvae, juveniles, and adults can occur on mud or mud-sand bottoms, but prefer firm bottom (28). They are usually attached to rocks, debris, or other oyster shells (20,113,159).

Physical/Chemical--Pacific oyster occurs in mesohaline-euhaline waters of 10-35 ppt and spawning is optimal in polyhaline waters of 20-25 ppt (20,22,154). It can tolerate air temperatures down to -4°C and water temperatures up to 35°C (22,23). Spawning occurs at temperatures between 14 and 30°C (24°C optimum; seldom below 18°C) (84,191) and larvae survive at 17.5-35.0°c (22). Adults grow best at 17-28°C and can continue feeding down to 3°C; growth stops when temperatures fall below 10°C (20,154).

MIGRATIONS AND MOVEMENTS

This is not a migratory species. Passive movement of pelagic larvae results from water currents and, when benthic, larvae crawl along the bottom searching for suitable substrate. Juveniles and adults are sessile and are cemented to hard material on the bottom (154).

POPULATION CHARACTERISTICS

Two subspecies have been described: C. gigas gigas, indigenous to the Northwest Pacific (and introduced to other Pacific regions), and C. g. angulata, which occurs in western Europe (121,159,191). As stated in the RANGE section, these subspecies may actually be separate species. Pacific oyster has been cultured in Japan since around the 16th century (28).

REPRODUCTION

Mode--Sexual and oviparous (154). The Pacific oyster is protandric, developing first as males and later changing to females (28,122,154). Sex determination can be influenced by environmental conditions--females become males when food supply is low, and males become females when food supply is high (154).

Spawning--Spawning is stimulated by a rise in water temperature (usually to at least 18°C) or by hormones released from the sperm of other spawning oysters (4). This species spawns between June and September during high-tide periods in areas from the lower intertidal zone to depths of 7 m (84,154,159). Since minimum threshold water temperatures are usually required, reproduction may not occur every year. Reproduction occurs annually in British Columbia (from Pendrell Sound and the Strait of Georgia to Tofino Inlet on the west coast of Vancouver Island) and in Washington (Puget Sound and parts of the outer coast). In Willapa Bay, reproduction every third year is sufficient to maintain stocks of commercial importance for growers (95). Reproduction occurs less frequently from there south to Tomales Bay, California (154,157). Rather than releasing ova through the exhalant channel like other bivalves, Pacific oyster eggs are discharged into the superbranchial chambers, released through the gills into the mantle chamber, and then discharged out of the female. They are propelled 30 cm or more. The female discharges eggs 5-10 times per minute. The male discharges a continuous stream of sperm with his exhalant water (154).

Fertilization--External; in the water column during spawning (154).

Reproductive Potential--This species spawns about 10 million to 200 million eggs annually; fecundity increases with age (33,65). An individual may spawn repeatedly during a spawning season and yearly throughout its life (84).

Release of Larvae--Early life stages occur in the upper 4 m of the water column between June and September (154).

GROWTH AND DEVELOPMENT

Egg Size--0.05 mm (154).

Embryonic Development--Indirect and external (154). Fertilized eggs develop within 24 to 48 hours into a veliger larvae, which remain pelagic for 2-4 weeks (this pelagic period decreases with increasing temperatures (84,154)), until the larvae cement themselves to the substrate (33).

Larval Size Range--0.06 mm - 0.32 mm (95).

Juvenile Size Rance--Probably 0.30 mm to about 40.0 mm. Sizes vary according to tidal height and the area in which they occur (28,154).

Age and Size of Adults--Shell and body growth in Pacific oysters is extremely variable, and depends upon temperature and food supply (154). They can mature at 1 year of age and have a shell length (S.L.) as small as 30 mm (28). Unharvested adults may live 20 years and reach 344 mm in length (8,841.

FOOD AND FEEDING

Trophic Mode--Detritivore-nannoplanktivore (20,84).

Food Items--Larvae feed on naked flagellates (22), whereas juveniles and adults eat nannoplankton (e.g., bacteria, dinoflagellates, flagellates, diatoms, and algal and invertebrate gametes). They also feed on detritus from disintegrating plant and animal cells (20).

Feeding Behavior--Larvae feed in the water column; other life stages are benthic suspension-feeders. They filter particles through mucous on the gills during respiration. The particles are transported to the mouth by cilia where larger items are rejected by the palps (20). Intertidal feeding occurs during high-tide periods.

BIOLOGICAL INTERACTIONS

Predation--The larvae are eaten by ciliated protozoa (family: Tintinnidae), ctenophores, jellyfish, mussels, oysters, barnacles, herring, and smelt (22). Spat are eaten by turbellarian flatworms and crabs (95,154). Juveniles and adults are prey for oyster drills, crabs (e.g., Pacific rock crab, slender crab, Dungeness crab, and most important, red rock crab), seastars (e.g., leather stars, mottled stars, ochre stars, sunflower stars), and bat rays (20,154). Their hard shells protect adults from many predators, and the valves can remain closed for several days (20).

Competition--This species may successfully compete with the native oyster (Ostrea lurida) in some areas since they feed on smaller prey, grow faster, and reproduce at a greater rate than native forms (20). However, the Pacific oyster is more restricted than the native oyster in its depth range and reproduction requirements (23,84).

Symbiotic Relationships--Epiphytic plants and animals live on oyster shells, and boring sponges and polychaete worms (Polydora spp.) penetrate the shell (168,191). Commensal spirochetes occur in the crystalline style and trematode sporocysts and cercaria are sometimes found in the flesh (191). A parasitic fungus (Dermocystidium sp.) sometimes kills oysters but is harmless to man (4).

Social Interactions--Pacific oysters settle onto the shells of their own species. In the wild, they may form beds that are several meters thick, although live oysters occupy only the top layers (28,113).

Community Associations and Interactions--Many epiphytic and epibenthic organisms occur in oyster beds including filamentous green algae (Enteromorpha), eel grass, sponges, anemones, flatworms, nemertean and polychaete worms, snails, nudibranchs, clams, barnacles, amphipods, isopods, shrimps, crabs, seastars, sea urchins, and tunicates (154).

FACTORS INFLUENCING POPULATIONS

Low temperatures inhibit spawning in many areas (65). Larval mortality may be related to low temperatures, excessive turbidity, lack of food, toxins from dinoflagellate blooms, and bacterial or fungal diseases (22). Excessive turbidity may reduce settling sites (22). In addition to predation, adult populations may be adversely affected by storms that can wash individuals ashore or bury them in sediments, by ice (in northern regions) that pushes them into the sediments, by algal blooms that inhibit feeding, and by burrowing ghost shrimp that bury oysters with sediment (20,154,157). In addition, dredging in estuaries and pollution affect populations by smothering or poisoning oysters (157). Pollution is the primary cause for the near total elimination of current oyster harvests in California (harvests as recent as the mid-1970s annually averaged over 340 t (131,162)). In general the extent of commercial oyster beds depends upon the amount, quality, and survival of planted seed oysters (65).

PACIFIC GEODUCK, Panope abrupta (Conrad 1849) (23), often referred to as Panopea generosa in the literature.

(geoduc, geoduc clam, geoduck, geoduck clam, giant panopaea, goeduck, gooey-duck, gueduc, gweduc, king clam (30,69,84,123,160))

Classification

Phylum--Mollusca

Class--Bivalvia

Order--Myoida

Family--Hiatellidae (23,84)

MANAGEMENT

Because Pacific geoduck is a coastal species, it is not covered by U.S. federal fishery management plans. Harvests are regulated by state agencies in Washington and California and by the Canada Department of Fisheries and Oceans in British Columbia (39,184,192). Since commercial harvests involve the leasing of subtidal lands, management of this species may be somewhat more complicated than other fishery resources (e.g., in Washington, the Departments of Natural Resources and Fisheries are both involved with geoduck harvests) (160).

VALUE

Commercial--Although this species was not commercially harvested until 1970 (182), its importance grew rapidly and Pacific geoduck now supports the largest commercial clam fishery on the west coast of North America (160). In recent years (1981-83), harvests averaged nearly 4,900 t annually and are 60% of the total coastwide commercial clam harvest (12,32,37,38,40,43,44,45,110, 111,183,185). It has provided U.S. fishermen with an income of up to $2.4

million annually ($1.4 million, 1981-83 average) (183). This species is taken commercially from southeast Alaska to Washington, but is mostly dug in regions of southern British Columbia and Puget Sound. Important harvest areas include the west coast of Vancouver Island (Kyuquot Sound to Clayoquot Sound) and southern Puget Sound (Vashon Island to Budd Inlet). Each of these regions has produced 40% of recent annual coastwide harvests. Other areas that have accounted for 2-6% of recent totals include the British Columbia mainland coast near Milbank Sound (6%) and Fitzhugh Sound (2%), the east coast of Vancouver Island between Oyster Bay and the Gulf Islands (6%), Barkley Sound (3%), and the northern part of Puget Sound from lower Admiralty Inlet to Possession Sound (2%) (32,43,44,45,185). Harvest areas in southeast Alaska include beds off Noyes Island and the west side of Gravina Island (105). [Authors' note: Alaska harvests are low; the resource is underutilized because the extent of its range is unknown and most beds are remote (105).]

Pacific geoduck is harvested subtidally (to about 20 m) by divers with hand-held, high-pressure water jets (daylight only). Suction devices are legal but not known to be used (79,160). In Washington, this species is taken on subtidal tracts leased from the state. These tracts must be more than 200 yds (182 m) offshore from the mean high-water line and have depths greater than 5.5 m below mean lower low water (MLLW) (160). Pacific geoduck is harvested throughout the year, but most (at least in British Columbia) are taken during spring and summer (80% of the total is taken from March to August) (43,44,45).

This species has an excellent taste; 56% of an individual is edible meat (4,73). It is sold whole or as fresh or frozen steaks and chowder meat, and frozen steaks are exported to Japan (where it is eaten raw as sushi). Meat quality is somewhat related to substrate; coarse substrate produces higher quality (80).

Geoduck harvested from Canada are higher quality than are those from Washington (160). For example, the price paid fishermen in 1984 for British Columbia geoduck was more than twice that paid for Washington geoduck (150,186) (1981-84 price range in Washington, $.10-.47/lb (186)). The entire coastwide harvest is taken by domestic fishermen; U.S. harvesters account for about 40%. Pacific geoduck larvae are cultured for seeding new beds (78).

Recreational--The Pacific geoduck is harvested recreationally from British Columbia to California and is particularly important in Washington (39,160,192). It is harvested throughout the year from the intertidal zone with a shovel and with large open-ended tubes implanted in the sediments surrounding the geoduck siphon (160).

Ecological--This species is the largest burrowing bivalve on the Pacific Coast of North America and an important member of the benthic community in Puget Sound (78,160).

RANGE

Worldwide--The Pacific geoduck is a temperate amphi-North Pacific species that occurs along Japan from Kyushu to Hokkaido Islands (23,108), in the Northeast Pacific from southeast Alaska to Baja California, and in the northern Gulf of California (23,84,137).

Within Study Range--It ranges from lat. 58°N in southeast Alaska to Scammons Lagoon, Baja California Sur (23,60). It is abundant along most of the coast of Vancouver Island, in the Strait of Juan De Fuca, and in Puget Sound (30,160). This species is uncommon in California but it is found occasionally in Morro and San Pedro Bays (84).

LIFE MODE

Eggs and larvae are pelagic. Juveniles and adults are benthic infauna (78,84) and burrow to a depth of 100 cm; juveniles <2 years burrow only to 60 cm (76).

HABITAT

Type--Juveniles and adults occur from the lower intertidal zone to 110 m (99) in bays, sloughs, and estuaries (23,61,84). Distribution in Alaska is restricted to subtidal areas and depths of about 4.5-12 m (106).

Substrate--This species is found in substrates ranging from mud to peagravel-gravel, but it is mostly found in unshifting mud or sand (80).

Physical/Chemical--The eggs and larvae occur in polyhaline-euhaline water of 22.0-35.0 ppt (optimum: 27.5-32.5 ppt) (75). Juveniles and adults are mesohaline-euhaline and tolerate salinities of 5.0-35.0 ppt (above 25.0 ppt preferred) (15,75). Spawning occurs at 8-16°C (optimum: 12-14°C) (73). Larvae survive at 6-18°C, although they prefer temperatures below 17°C (75). Juveniles and adults tolerate air and water temperatures of 0-25°C, but only occur in regions where water temperatures between April and July (the spawning season) are lower than 16°C (15,75,73).

MIGRATIONS AND MOVEMENTS

The eggs and larvae are dispersed by water currents. Juveniles and adults are immobile and remain in the same area for life.

POPULATION CHARACTERISTICS

Pacific geoduck occurs at densities up to 14.7 per m^2 off Vancouver Island (30) and up to 22.5 per m^2 in Puget Sound (average 1.7) (80). Density is related to water depth; highest densities occur in water depths of 9 to 14 m in Washington (80). In Puget Sound, the stock is estimated to be 127,000 t

(at 10-30 m) (164), and in southern British Columbia, it is estimated to be at least 115,000 t (at 0-18 m) (85). At least three disjunct subpopulations of this species occur in Japan, in southeast Alaska to central Baja California, and in upper Gulf of California (23,84,108,137). The Japanese population has often been considered a separate species (23).

REPRODUCTION

Mode--Sexual, separate sexes, oviparous (15,78).

Spawning--Occurs between April and July and has been observed at 8-12 m in Hood Canal, Washington (73). It is stimulated by a rise in water temperature or the presence of geoduck sperm in the water (75). Introduction of high concentrations of algae into hatchery waters also induces spawning (79). During spawning, eggs and sperm are discharged from the exhalant siphon and flow continuously for either several minutes or up to over an hour (78).

Fertilization--External, occurring in the water column (61).

Reproductive Potential--Fecundity ranges from 7.5 million to 20 million eggs per female during a single spawning (78). Each clam can spawn at least twice during a season (78). Despite high fecundity, recruitment is generally low (167).

GROWTH AND DEVELOPMENT

Egg Size--0.08 mm (78)

Embryonic Development--Indirect and external. Embryos begin development on the day of fertilization and become free-swimming trochophore larvae within 10-12 h (160). They transform into veliger larvae shortly thereafter (within about 24 hours of fertilization (61). The larvae remain in the water column for several weeks (30 days at 6.7°C; 47 days at 14-15°C (78)) before metamorphosing into juveniles and settling to the bottom. Settling peaks in

mid-July (15).

Larval Size Range--0.11 mm to 0.35-0.40 mm (pelagic); 0.35-0.40 mm to 0.80 mm (epibenthic) (78).

Juvenile Size Range--0.8 mm to 60.0-100.0 mm (15,78).

Age and Size of Adults--This species is long lived and slow growing. In Puget Sound, males mature at 3 years and 60-100 mm S.L.; females at 4 years and 100-120 mm (15). Age at maturity in British Columbia is 5 years (167). Growth is rapid for the first 4 years but then greatly decreases (164). It takes 8-10 years to reach market size; some individuals live 146 years (30,160,167). Maximum size is 23 cm S.L., 1.5 m total body length (from foot to extended siphon tip), and 9.1 kg (33,107,133).

FOOD AND FEEDING

Trophic Mode--Filter-feeder/suspension-feeder.

Food Items--The larvae eat flagellates of the order Isochrysidales (78). Juveniles and adults feed on detritus and plankton (61).

Feeding Behavior--During feeding, water is sucked in through the inhalant siphon and expelled through the exhalant siphon. Food particles are filtered from the water by the gills and sorted by palps (61). Intertidal clams feed only during high tide periods.

BIOLOGICAL INTERACTIONS

Predation--Small individuals are eaten by northern moon snails and spiny dogfish (15,60); juveniles and adults are eaten by pink seastars and sunstars (166). Siphon tips of juveniles are eaten by cabezon and probably by starry flounder (15). Dislodged individuals are eaten by slender crab, Dungeness crab, and red rock crab (30).

As a defense against predation this species burrows into the sediment. When threatened, the siphons are retracted by shooting water about 1 m into the air when in the intertidal zone (24,61). The siphons are also retracted when the clam is inactive, and the siphon hole is buried (82). Seastar predation can be appreciable when this clam's escape is obstructed by an underlying impenetrable layer of substrate (166).

Competition--This species may compete with fat gaper and Pacific gaper clams where their ranges overlap.

Symbiotic Relationships--Gastropod egg capsules are sometimes attached to the siphon tips. A copepod (Paranthessius panopea) and pea crabs are commensal in the mantle cavity (15). The bay goby lives commensally in the siphon hole (82).

Social Interactions--Undescribed.

Community Associations and Interactions--Plants and animals most commonly associated with geoduck beds (in Puget Sound) are chaetopterid polychaetes (Spiochaetopterus costarum and Phyllochaetopterus prolifica), sea cucumbers, sea pens, Laminaria kelp, and horse clams (80). Other sources indicate associations with red algae (Pterosiphonia dendroidea), eelgrass, slender crab, red rock crab, and flatfishes (15,30).

FACTORS INFLUENCING POPULATIONS

Although larvae of Pacific geoduck experience extremely high mortality, which results in a low recruitment rate, the natural mortality rate of adults is low ($M<0.05$) (30,78). Adults experience low predation but may die when vegetation accumulates on the beach and rots above their siphons, or when their shells are cracked by earthquakes or slumping of the sediments (15). In addition to mortality due to harvesting, adults are also killed during dredging operations.

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PACIFIC LITTLENECK CLAM, Protothaca staminea (Conrad, 1837) (23)
(bay cockle, common littleneck, hardshell, native littleneck, Petit's rock-Venus, ribbed carpet shell, ribbed rock-venus, rock clam, rock cockle, round rock-Venus, ruderated rock-Venus, steamer clam, and Tomales Bay cockle (25,50,61,69,102,156>. Common littleneck and native littleneck frequently used.)

CLASSIFICATION

Phylum--Mollusca

Class--Bivalvia

Order--Veneroida

Family--Veneridae (23,84)

MANAGEMENT

This is an inshore species that is not covered by any federal fishery management plan in the United States. Its harvests are regulated by state fishery agencies in Alaska, Washington, Oregon, and California, and by the Canada Department of Fisheries and Oceans in British Columbia (11,39,140,162,184).

VALUE

Commercial--This species has been harvested commercially from Prince William Sound, Alaska, to southern California (11,61) with a variety of devices such as potato forks, shovels, clam hacks (rakes), and hydraulic dredges (160). Coastwide harvests are difficult to determine since some landings of this species are lumped with several other clam species in catch statistics. From the information available, littleneck clam landings constituted about 8% of the entire clam harvest along the west coast of the United States and Canada

during 1981-83. Annual catches averaged over 630 t, ranking third in total volume behind geoduck and Manila clams (12,32,37,38,40,43,44,45,110,111).

Most harvests occur in intertidal areas of British Columbia (28) and in both intertidal and subtidal locations of Washington. Principal harvest areas include British Columbia waters at Alert Bay and the northern portion of the Strait of Georgia (44% of coastwide total), and Washington waters in northern Puget Sound from Dungeness Spit to Admiralty Inlet (40% of total) (12,28,43,44,45,185>. Of the entire 1981-83 harvest, 41% came from Washington, 40% from British Columbia, and most of the remaining 19% was offloaded in Washington from unknown areas outside that state. Populations in Alaska and California are largely unexploited (65,160), and stocks in Oregon are quite small because of limited habitat (only 24 t taken in 1981-83 (32,110,111)). This is a highly esteemed food species and is sold fresh in the shell (61,153). Harvests occur throughout the year, although they are slightly higher from January to May (43,44,45).

Recreational--The Pacific littleneck clam is harvested year-round throughout most of its range. It is usually taken at low tide during the day with a variety of hand implements such as garden trowels, rakes, and shovels (39,61,65,183).

Ecological--This is one of the most abundant clams along the west coast of North America and it is an important suspension-feeder on protected gravel-mud beaches (51,184).

RANGE

Worldwide--The Pacific littleneck clam is a boreal, Pacific species that occurs in intertidal and subtidal regions of the North Pacific. Overall distribution is somewhat unclear; some sources indicate a distribution around the Pacific rim from the northern Sea of Japan to Socorro Island, Mexico

(51,159), whereas most others limit its range to the Northeast Pacific. (5,28,61,84,151,160).

Within the Study Area--It occurs throughout the Aleutian Islands and from the southeastern Bering Sea south to Cape San Lucas, Baja California Sur (61,84). Areas of abundance are those mentioned in the commercial fisheries section. Other common occurrence areas include: the north and south coasts of the Alaska Peninsula and numerous protected bays throughout Alaska; beaches in the southern Strait of Georgia and Strait of Juan de Fuca in British Columbia; most of Puget Sound and in Willapa Bay in Washington; Tillamook, Yaquina, and Coos Bays in Oregon; and Bodega and Tomales Bays, Malibu Point, Marina del Rey, the Palos Verdes Peninsula, and from Newport Bay to San Mateo Point in California (12,43,44,45,61,103,160,185).

LIFE MODE

The eggs and larvae are pelagic. Juveniles and adults are benthic infauna (28,84), and occur in the upper 15-20 cm of the seabed, seldom deeper than 5-7 cm (61,151,160); large individuals are found deeper in the substrate than small ones (5).

HABITAT

Type--The eggs and larvae are estuarine-neritic. Juveniles and adults occur from the high tide mark to 37 m in bays, estuaries, and along protected open coasts (21). They are usually found at depths less than 10 m (72) and are most abundant in the lower intertidal zone to 0.4 m above MLLW (6,60,77).

Substrate--In bays and estuaries this species occurs in sediments ranging from mud to cobble (77), but it prefers firm, gravelly (151) or clayey-gravel sediments (157). Along the open coast it is found in coarse sand, gravel, and cobble near rock points and reefs or under large rocks (61,84).

Physical/Chemical--The Pacific littleneck clam occurs in mesohaline-euhaline waters 2-27°C (23).

MIGRATIONS AND MOVEMENTS

The eggs and larvae are dispersed by water currents. Juveniles and adults are immobile and remain in the same area for life.

POPULATION CHARACTERISTICS

Population structure is largely undescribed for Pacific littleneck clam. Sizable aggregations occur throughout the distribution with up to 150 (legal size) clams per m^2 in southern California (65) and up to 368 harvestable clams per m^2 in Prince William Sound (60). Worldwide distribution is unclear because it is associated with several subspecies; at least seven subspecies are cited in the literature (51,159).

REPRODUCTION

Mode--Sexual, separate sexes, oviparous (65).

Spawning--This occurs during spring and summer; timing varies by region (e.g., from April to September in British Columbia and from late May to mid-June in Prince William Sound, Alaska (51,84)). During spawning, eggs and sperm are discharged from the exhalant siphon (61). This activity occurs at temperatures of 5.6-13.6°C in Prince William Sound (51).

Fertilization--External, in the water column (65).

Reproductive Potential--Undescribed. Individuals presumably spawn several times during a spawning season (61).

GROWTH AND DEVELOPMENT

Egg Size--About 0.06 mm (51).

Embryonic Development--Indirect and external. Embryos begin development upon fertilization, become free-swimming trochophore larvae in 10-12 hours, and transform into veliger larvae shortly thereafter (within about 24 hours of fertilization) (160). The larvae presumably remain in the water column for several weeks before they metamorphose into juveniles and settle to the bottom.

Larval Size Range--About 0.06-0.25 mm (6,152).

Juvenile Size Range--0.25 to 13-35 mm (9,84,152).

Age and Size of Adults--Size at maturity is 13-35 mm S.L. throughout the range of the Pacific littleneck clam, although growth varies by region. For example, harvestable size (30 mm) is achieved in 3-4 years in British Columbia (151), 6 years in southeast Alaska (145), and 6-10 years in Prince William Sound (6,60). The largest size reported is about 80 mm (157) and maximum age is about 13-15 years (5).

FOOD AND FEEDING

Trophic Mode--Filter-feeder/suspension-feeder (146).

Food Items--This species feeds on detritus and plankton (61); the importance of detritus in its diet is not understood (28).

Feeding Behavior--During feeding, water is sucked in through the inhalant siphon, and food is filtered from the water by the gills and sorted by the palps (61).

BIOLOGICAL INTERACTIONS

Predation--Pacific littleneck clam is eaten by oyster drills, northern and southern moon snails, two-spotted octopus, several Cancer crabs, mottled sea stars, and several fishes (25,59,93,146,160). Young juveniles are eaten by ducks and other birds (160).

Competition--Undescribed. In southern California, this species may compete with the wavy chione cockle (146).

Symbiotic Relationships--This species is sometimes infested with larval trematodes and cestodes (61,170). The obtuse fossarus snail is sometimes attached to the shell (152). Mussel crabs and pea crabs live commensally in the clam's mantle cavity (68).

Social Interactions--Intraspecific competition for space may reduce growth and reproductive rates (146).

Community Associations and Interactions--Pacific littleneck clam commonly occurs with the butter clam, thin-shelled littleneck clam, and the Manila clam in the Pacific Northwest (107,160). In southern California it occurs in assemblages dominated by the yellow metis, but also occurs with the ribbed horse mussel, bay mussel,, wavy chione cockle, smooth Pacific Venus clam, northern quahog, and the California jackknife clam (50,159).

FACTORS INFLUENCING POPULATIONS

Pacific littleneck clam populations fluctuate greatly in the absence of exploitation (65). Mortality is high among young and old individuals (84). Runoff during storms may kill clam beds by covering them with sediment or by eroding away sediments and exposing the clams to predators (65). The quality of the meat is affected by sewage pollution, and harvests of this species have been declining in some regions for the last 20 years (50,160).

PACIFIC RAZOR CLAM, Siligua patula (Dixon, 1789) (23)

(California razor fish, flat razor shell, giant pod, northern razor clam, razor clam, razor shell, sea clam (24,69,123))

CLASSIFICATION

Phylum--Mollusca

Class--Bivalvia

Order--Veneroida

Family--Solenidae

MANAGEMENT

The Pacific razor clam is a coastal resource that is managed by the states of Alaska, Washington, Oregon, and California. Harvests in British Columbia waters are monitored by the Canada Department of Fisheries and Oceans (11,39,141,142,162,184).

VALUE

Commercial--Although historically an important commercial species, its commercial significance has diminished in recent years because of ever-increasing recreational fisheries, depleted stocks, diseases, toxicity, and substantial changes in the commercial clam market (160). Annual coastwide commercial landings in recent years (1981-83) have averaged only about 275 t, which is a small fraction of the amounts taken throughout the early part of the century (e.g., 1,400 t of meats from 1913 to 1932 (160,183)). Despite a decline in importance, this species is still harvested by commercial fishermen, especially in Alaska where it is used as bait for Dungeness crab (160).

Pacific razor clam is harvested from open ocean sandy beaches from western Alaska to Oregon (11,84), mostly with hand shovels and forks and occasionally by hydraulic or mechanical clam diggers (11,140). A special permit is required in Alaska (11). Specific commercial harvest locations include three areas in Alaska (Swikshak Beach on the Alaska Peninsula, the Polly Creek area on the west coast of Cook Inlet, and near the Copper River Delta (mainly Kanak Island) outside Prince William Sound); the northeast coast of Graham Island in British Columbia; outside Willapa Bay in Washington; and at several locations in Oregon, most of which are just south of the Columbia River. In addition, native Americans make substantial commercial harvests on beaches of the Quinault Indian Reservation north of Grays Harbor, Washington (200 t annually from 1970 to 1980) (160). [Authors' note: references 43,44,45 list harvests in several British Columbia subareas other than for the northeast part of Graham Island. These are reporting errors; there are no commercial razor clam catches occurring outside the Canada commercial statistical fishery subarea 1 (28).]

Harvests can occur throughout the year, but north of central Oregon, harvest is sometimes restricted during the summer because of the potential presence of paralytic shellfish poisoning contamination (157), concern for overharvesting, and wastage of newly recruited clams (177). Commercial fishing is prohibited in California (162). Pacific razor clam is harvested entirely by domestic fishermen and the (non-Indian) commercial catch is split between the United States and Canada in the ratio of 85:15 (1981-83 catch statistics) (12,31,43,44,45,177). This species has an excellent flavor and has a high edible meat content (24). The Pacific razor clam is cultured in Washington (160).

Recreational--Pacific razor clam is more important recreationally than commercially (160). Several beaches in Washington have been closed to

commercial harvests and are only available for recreational catches (160). This species is taken recreationally from Kodiak Island, Alaska, to Pismo Beach, California (129,160). Specific digging areas include: the east side of Cook Inlet (Homer Spit to Cape Kasilof) and Prince William Sound in Alaska; Grayland, Long Beach, Copalis Beach, and Mocrocks Beach in Washington; several beaches in Oregon; and mainly at Morro Bay and Pismo Beach in California (129,160). It may be taken year-round, but because of paralytic shellfish poisoning contamination, depleted stocks, or other conservation concerns, harvests are prohibited in some years in areas of Washington and California (39,184). This species is dug by hand, spade, or tube gun (107,142,160). Annual recreational harvests for the U.S. west coast and Alaska for 1969-76 (the most recent years of available data) averaged about 9.5 million clams (roughly 1,000 t), with about 80% coming from Washington (165).

Ecological--This species Is a major infaunal suspension feeder on intertidal, exposed, high-energy beaches from Alaska to central California. It is a major food item for Dungeness crab and numerous bottom-feeding fishes (165).

RANGE

Worldwide--Pacific razor clam is a boreal, Pacific species with a range that lies entirely within the region covered by the Data Atlas (64,100,160).

Within Study Area--It ranges from the eastern Aleutian Islands (at least Kalekta Bay, Unalaska Island) to Pismo Beach, California (64,160). Areas of abundance in addition to those mentioned in the commercial and recreational fisheries sections include: Kalekta Bay, the north shore of the Alaska Peninsula from Bechevin Bay through Izembeck Bay, several locations along the south coast of the Alaska Peninsula from Stepovak Bay (San Diego Bay) to Hallo Bay, around Kodiak Island, along the outer coast of the northern Gulf of Alaska from Montague Island to Cape Spencer, and Kruzof Island in Alaska; Long

Beach on the west coast of Vancouver Island, British Columbia; from the Columbia River to Copalis Rocks, Pacific Beach, Tahole, and Kalaloch in Washington; from the mouth of the Columbia River to Tillamook Head in Oregon; and at Crescent City and Clam Beach (Humboldt County) in California (28,64,129,153,160).

LIFE MODE

Eggs and larvae are benthopelagic. Juveniles and adults are benthic infauna (84).

HABITAT

Type--Eggs and larvae are sublittoral. Juveniles and adults are found from the lower intertidal zone (+1.37 m) to 55-61 m along exposed beaches (21,129,133) and apparently concentrate between +61 m and -0.31 m of MLLW in Alaska (129). They occur subtidally only in Yakutat Bay, Alaska (106).

Substrate--Juveniles and adults occur on flat or gently sloping beaches of shifting sand (64,84).

Physical/Chemical--This species occurs in mesohaline-euhaline waters with salinities as low as 15.5 ppt (158). It survives in temperatures of 1-22.5°C (LD-50 at 4 hours is 22.7%) (158). A threshold temperature for spawning is 8.3°C in Alaska (129). This species occurs primarily on beaches with moderate to heavy surf (64).

MIGRATIONS AND MOVEMENTS

Eggs and larvae are dispersed by ocean currents. Juveniles ((10 mm S.L.) are capable of lateral movement up to 60 cm; larger juveniles and adults are probably unable to move voluntarily (129). Subtidal juveniles may move shoreward to populate intertidal beaches (28).

POPULATION CHARACTERISTICS

Extensive movement only during larval stage and specific substrate requirements result in numerous relatively isolated populations. For example, beds of this species have been identified in at least 49 separate locations in Alaska (129).

REPRODUCTION

Mode--Sexual, separate sexes, oviparous (64).

Spawning--Timing varies annually and regionally. The overall range, late spring to early fall, appears to be governed by a combination of time and temperature. After a minimum of 1,350 temperature units (i.e., cumulative °F of the maximum daily deviation from 32°F that are observed from 1 January) (129) is achieved, a threshold temperature is needed for spawning to commence: about 8.3°C in Alaska (39) and apparently 12.7°C in Washington (64). In general, spawning occurs from June through September (mainly July through August) in Alaska (129,135), during July in British Columbia (151), from May through June in Washington, and during fall in California (64). During spawning, the eggs and sperm are discharged from the exhalant siphons (61). From Washington to California, all individuals in a bed spawn simultaneously; this is not the case for beds to the north (157).

Fertilization--External, in the water column (64).

Reproductive Potential--Fecundity varies by size from 0.3 million-0.7 million ova at 40 mm S.L. to 118 million-245 million ova at 180 mm S.L. (129). Females may spawn several times within a season (61).

GROWTH AND DEVELOPMENT

Egg Size--Average diameter is 90 microns (31).

Embryonic Development--Indirect and external (160). Fertilized eggs develop into free-swimming veliger larvae within 3-4 days (64). The larval period lasts 30-40 days depending on the water's temperature (129).

Larval Size Range--90-256 microns (31).

Juvenile Size Range--256 microns to 61-86 mm (129).

Age and Size of Adults--Sexual maturity is more size dependent than age dependent (129). An approximate size for the onset of maturity is 60 mm S.L. (129). In Alaska, some mature during their third year of life (129), and in California in their second year (64). Pacific razor clam is apparently mature by age 6+ years, at a size of 113.1-134.1 mm S.L. (129). Maximum age is 18 years in Alaska (129), 8 years in Washington (165), and 8 years in California (64) (currently 5-8 years in California (165)). Maximum shell size is about 180 mm S.L. (129), and total length from the foot to the siphon may reach 356 mm (61,168); maximum weight is about 395 g (129).

FOOD AND FEEDING

Trophic Mode--Filter feeder/suspension feeder.

Food Items--Feeds on the diatom Chaetoceros armatus (176).

Feeding Behavior--Water is sucked into the inhalant siphon, filtered by the gills, and expelled through the exhalant siphon. Food particles are then guided to the mouth by cilia and a pair of palps (64).

BIOLOGICAL INTERACTIONS

Predation--This species is eaten by Dungeness crab, starry flounder, surfperch, sturgeon and other bottom feeding fishes, shorebirds (sandpipers and gulls), and sea ducks (surf scoter and white-wing scoter) (81,84,165,176). It is a rapid burrower and can dig at a rate of 22.8 cm per minute (24).

Symbiotic Relationships--This species harbors commensal nemerteans (Malacobdella grossa) and pea crabs in its mantle cavity (103,168,177).

Community Associations and Interactions--Pacific razor clam co-occurs with S. alta from lower Cook Inlet to western Alaska, although S. alta usually occupies finer substrates (129). Pacific razor clams off Washington are replaced by a similar species, S. sloati, at depths greater than 8 m (160).

FACTORS INFLUENCING POPULATIONS

Juveniles are often dislodged by storm surf and eaten by predators (160). Until recent years, recreational fishing pressure has been heavy along the Washington and Oregon coasts; nearly all razor clams are harvested by their third year of life (165).

Natural disasters substantially influence populations. Entire clam beds were lost after the Alaska "Good Friday" Earthquake of 1964 when several beaches rose 2 m above their previous height (158,160). Other natural phenomena that disrupt populations include El Niño events (165), the Mount Saint Helens eruption in 1980, and disease. Between June 1983 and January 1984, a pathogen known as "NIX" (Nuclear Inclusion--X) presumably caused 95% mortality to razor clam populations along the central coast of Washington. Additionally, an unidentified prokaryotic bacteria-like pathogen has been found in virtually all Washington coast razor clams since 1983. The occurrence of this pathogen resulted in the total closure of razor clam digging in 1984 and 1985 (58).

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CALIFORNIA JACKKNIFE CLAM, Taselus californianus (Conrad,1837) (23)

(California razor clam, California short razor, Californian tagelus, jackknife clam, razor clam, short razor clam (6,69,102))

CLASSIFICATION

Phylum--Mollusca

Class--Bivalvia

Order--Veneroida

Family--Psammobiidae (23,84)

MANAGEMENT

Because the California jackknife clam is a coastal species, it-is not covered by any federal fishery management plan in the United States Its harvests are regulated by the California Department of Fish and Game (162).

VALUE

Commercial--This species has commercial importance only in California and is commercially harvested from Elkhorn Slough in Monterey Bay to Mission Bay, California, just north of the U.S.-Mexico border (55,62). Harvesting is heaviest in southern California (62) but information does not indicate how much of California's annual clam harvest (25 t In recent years) is composed of this species. Harvesting began in 1962 (1) and during the mid-1970s, annual harvests averaged about 6 t (160). Although it has a good flavor, it is seldom eaten and mostly sold for bait (62,160).

Recreational--This clam is also taken recreationally for bait and occasionally for food (24). Recreational harvests are in the same general regions as the commercial harvests (62,179).

Ecological--The California jackknife clam is a major infaunal suspension-feeder and prey for benthic-feeding fishes in the sloughs and estuaries of southern California.

RANGE

Worldwide--California jackknife clam is a temperate (Oregonian-Californian) Northeast Pacific species that is found from southern Oregon to the tip of Baja California and throughout the Gulf of California south to the vicinity of Mazatlan, Mexico (lat. 23°N) (23,47). Records from Panama are probably not of this species but rather of a related one (47,84).

Within Study Area--It ranges from about Cape Blanco, Oregon (lat. 43°N), to Cape San Lucas, Baja California Sur (23). It is most abundant south of Santa Barbara, California, but is not common north of Monterey Bay, California (62).

LIFE MODE

Eggs and larvae are pelagic. Juveniles and adults are benthic infauna (84) and burrow down 38-51 cm (62).

HABITAT

Type--The eggs and larvae are estuarine-neritic. Juveniles and adults occur from the lower intertidal zone from +0.2 m to -0.5 m in back bays, sloughs, and estuaries (47,62,163).

Substrate--Juveniles and adults occur on substrates from stable mud to sandy-mud bottoms (24,61).

Physical/Chemical--This species lives in mesohaline-euhaline waters where water temperatures range from 9 to 30°C (23).

MIGRATIONS AND MOVEMENTS

The eggs and larvae are dispersed by water currents, but after they settle out of the water column, juveniles and adults remain in the same area for life.

POPULATION CHARACTERISTICS

There is limited information on this topic. The literature indicates that in Newport Bay, California, this species has occurred in densities of up to 50 clams per m^2 (163).

REPRODUCTION

t&&--Sexual, separate sexes, oviparous (84).

Spawning--Reproduction occurs intertidally at high tide. Eggs and sperm are discharged from the exhalant siphon (62,163). The spawning season is undescribed.

Fertilization--External, in the water column (62,84).

Reproductive Potential--Undescribed. Presumably individuals spawn several times during the spawning season (62).

GROWTH AND DEVELOPMENT

Egg Size--Undescribed.

Embryonic Development--Indirect and external. Eggs begin development on the day they are fertilized. The trochophore and veliger larvae are pelagic, and presumably remain in the water column for several weeks.

Larval Size Range--Undescribed.

Juvenile Size Range--Undescribed.

Age and Size of Adults--Age and size at maturity and maximum age have not been described. Adults reach a size of 110 mm S.L. and the combined foot, shell, and siphon length is about 165 mm (113,163).

FOOD AND FEEDING

Trophic Mode--Filter-feeder/suspension-feeder.

Food Items--This species feeds on suspended organics, detritus, bacteria, and planktonic plants and animals (62,84,179).

Feeding Behavior--During feeding, water is sucked into the inhalant siphon, filtered by the gills, and expelled through the exhalant siphon. Cilia transport food particles trapped on the gill mucous to the mouth where they are sorted by palps (62,179). Feeding occurs during high tide.

BIOLOGICAL INTERACTIONS

Predation--California jackknife clams are eaten by ducks (102). For protection from predation, they live in permanent vertical burrows that are up to 51 cm deep (55). During feeding they occur in the upper 10 cm of the burrow, and their siphons protrude from separate holes. They retreat to the bottom of the burrow when threatened and can dig into the surrounding mud if necessary (24,62).

Competition--Undescribed.

Symbiotic Relationships--Undescribed.

Social Interactions--Undescribed.

Community Associations and Interactions--California jackknife clam occurs in assemblages dominated by yellow metis and Pacific littleneck clams (163).

FACTORS INFLUENCING POPULATIONS

California jackknife clam populations are probably affected by excessive freshwater run-off or evaporation, which may drastically change the salinities of their habitat. Dredging of back bays for harbors and pollution no doubt also affect the quantity of the habitat available to these clams.

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MANILA CLAM, Tapes philippinarum (Adams and Reeves, 1850) (23)

(Japanese cockle, Japanese littleneck, Manila cockle, Manila littleneck, Philippine cockle (153,183))

CLASSIFICATION

Phylum--Mollusca

Class--Bivalvia

Order--Veneroida

Family--Veneridae (23,84)

MANAGEMENT

The Manila clam is managed by the state agencies in Washington and California and by the Department of Fisheries and Oceans in British Columbia (27,39,162,184).

VALUE

Commercial--This highly esteemed clam is harvested commercially from British Columbia to California (27,43,44,45,162) with a variety of devices such as potato forks, shovels, clam hacks, and hydraulic dredges. Coastwide harvests are difficult to determine since landings of this species are sometimes lumped with several other clam species in catch statistics. According to available information, it accounted for over 20% of the entire U.S.-Canada Pacific Coast clam harvest during 1981-83 with average annual catches of at least 1,700 t. This amount was second in volume only to the geoduck harvest (13,32,37,38,40, 43,44,45,110,111,185).

Harvests are obtained from the intertidal zone (160,183), and in recent years (>90% during 1981-83) most have come from three regions: southern Puget Sound (45% of total), the Strait of Georgia (37%), and the west coast of

Vancouver Island (10%). Specific harvest areas in order of importance for 1981-83 are Carr Inlet-southern Puget Sound south of Dana Passage, the southeast coast of Vancouver Island from Parksville to the Gulf Islands (Canada commercial statistical fishery area 17, British Columbia), the British Columbia mainland coast and adjacent islands from Johnstone Strait to Powell River (statistical areas 13 and 15), and the Clayoquot Sound region of the west coast of Vancouver Island (statistical area 24) (43,44,45,185).

Minimum commercial size is 38 mm S.L. (2-year-olds in the southern part of their range, 3- to 4-year-olds in British Columbia) (27,65). This species has excellent flavor and is only sold fresh for steaming (153). Individuals in San Francisco Bay often accumulate pollutants and hence are less desirable (62). The larvae of this species are cultured to produce seed clams for stocking areas for mariculture (84).

Recreational--The Manila clam is one of the more important clam species harvested recreationally on the Pacific Coast (9). Since it lives just below the substrate, it is easy to hand harvest (160) and is taken from British Columbia to northern California by hand, fork, pick, rake, shovel, or garden trowel (62,94,183). It is taken intertidally during low tide periods throughout the year (39,65).

Ecological--The Manila clam is an introduced species that has been able to utilize a previously unexploited niche as a suspension-feeding clam in the middle and high intertidal zones of the protected coasts (27). It has become the dominant intertidal bivalve in many areas, including San Francisco Bay (65).

RANGE

Worldwide--The Manila clam is a tropical-temperate, western Pacific species that occurs naturally from the Philippines and China north along Japan to the

southern Sea of Okhotsk (123,159) and is now also present in Hawaii (123) and the Pacific coast of North America (1,7,17). It was accidentally introduced to the west coast from Japan with Pacific oysters (27).

Within Study Area--After accidental introduction to California and the Pacific Northwest in the 1930s, the North American range of this species has expanded to include numerous protected-water areas from Rescue Bay, British Columbia (27) to Elkhorn Slough, California (62,65). It is locally abundant in several areas, especially in the Strait of Georgia, southern Puget Sound, and San Francisco Bay. Attempts to intentionally introduce manila clams into northern coastal British Columbia, southeast Alaska, and southern California were apparently unsuccessful and did not establish self-sustaining populations (27,28,65).

LIFE MODE

The eggs and larvae are pelagic. Juveniles and adults are, benthic infauna and occur just below the sea bed surface, seldom deeper than 5 cm (10 cm maximum) (27,62,65).

HABITAT

Type--The eggs and larvae are estuarine-neritic. Juveniles and adults are mostly intertidal, and occur from the high intertidal zone (2.6 m above MLLW) down to perhaps 10 m subtidally (101). Most, however, occur intertidally so the highest abundance is 1.5-2.4 m above MLLW. Manila clam does not occur subtidally in British Columbia (27,71).

Substrate--Juveniles and adults live in coarse sandy mud, sand, and pea gravel (62,160) and are generally found in finer gravel substrates (28).

Physical/Chemical--This species lives in mesohaline-euhaline waters with salinities as low as 10 ppt (84). Juveniles and adults can tolerate

temperatures of 0-24.4°C, but maturation, spawning, and larval development require temperatures greater than 14°C (23,27,94). Juveniles and adults do not occur where maximum temperatures are less than 12% (27), they live in protected waters, and they are tolerant of pollution (65,94).

MIGRATIONS AND MOVEMENTS

The larvae are dispersed by water currents, but juveniles and adults remain in the same beach for life (27).

REPRODUCTION

Mode--Sexual, separate sexes (with an occasional hermaphrodite), oviparous (65,94).

Spawing--Reproduction occurs from June to September in Puget Sound and southern British Columbia, and possibly occurs later in areas north of there (27,94). It is stimulated by a rise in water temperature (94). Major spawning grounds include western Vancouver Island and Strait of Georgia in. British Columbia; Puget Sound, Grays Harbor, and Willapa Bay, Washington; and Humboldt and San Francisco Bays, California (136). During spawning, eggs and sperm are discharged from the exhalant siphon during high tide periods (62).

Fertilization--External, in the water column (62).

Reproductive Potential--The fecundity of this species is undescribed. Presumably, individuals spawn more than once during a spawning season (62).

GROWTH AND DEVELOPMENT

Egg Size--0.06 mm (62).

Embryonic Development--Indirect and external. Eggs begin development on the day they are fertilized (62). The ciliated motile trochophore larval stage forms within 24-48 hours (at 13-16°C), followed by a veliger stage which lasts

3-4 weeks. Following this, the veliger metamorphoses into a juvenile and settles to the bottom (27,28).

Larval Size Range--0.06 mm to 0.19-0.24 mm S.L.(28).

Juvenile Size Range--0.2 mm to 12-20 mm (28,94,136).

Age and Size of Adults--Adults mature at age 4-5 months and at 12-20 mm S.L. (94,136). They reach a maximum age of 10 years and a maximum size of 76 mm (65) . Growth is seasonal, mostly late summer (71), and none occurs in winter, at least in Washington. Rates of growth vary by geographic region (27) and vertical distribution along the intertidal zone.

FOOD AND FEEDING

Trophic Mode--Filter-feeder/suspension feeder.

Food Items--The Manila clam feeds on detritus and plankton (62).

Feeding behavior--During feeding, water is sucked in through the inhalant siphon and expelled through the exhalant siphon. Food particles are filtered from the water by the gills and sorted by palps (62).

BIOLOGICAL INTERACTIONS

Predation--Larvae are eaten by planktivorous invertebrates and fishes (62). Small juveniles are eaten by ducks and seabirds, and adults are eaten by the northern moon snail, crabs, seastars, and fish (160). As a defense against predators, they burrow 2-10 cm below the surface of the sediments (27,84). Their hard shells also provide defense against predation.

Competition--The Manila clam does not compete extensively for space with native clams because it occurs higher intertidally than native species (151).

Symbiotic Relationships--This species may have larval trematode cysts (28). Mussel crabs and pea crabs live commensally in the Manila clam's mantle cavity (68,84).

Social Interactions--Undescribed.

Community Associations and Interactions--The Manila clam occurs to some extent with other clams such as littlenecks, butter clams, softshelled clams, baltic macoma, and false mya, but generally occurs higher intertidally (68,153). It is also found with horse mussels, gastropods, shore crabs, and amphipods (136).

FACTORS INFLUENCING POPULATIONS

Because cold water is a barrier to larval survival, distribution to the north is restricted (27,153). Extremely cold air temperatures during the winter may freeze the intertidal zone at low tide and kill juveniles and adults (153). Harvesting adults can cause seed clam mortality if the seed clams (<9 mm) are accidentally covered by more than 8 cm of substrate (67). Laying plastic netting on clam habitat often provides a stable substrate and may substantially enhance clam concentrations (71).

PISMO CLAM, Tivela stultorum (Mawe, 1823) (23)

(giant tivela, great tivela, thickshell tivela)

CLASSIFICATION

Phylum--Mollusca

Class--Bivalvia

Order--Veneroida

Family--Veneridae (23,84)

MANAGEMENT

The Pismo clam is managed as a recreational species by the California Department of Fish and Game (39,162).

VALUE

Commercial--The Pismo clam has not been commercially harvested in the United States since 1947 (65,162), although since that time canned products have been imported from Mexico (65).

Recreational--This is an important recreational species in central and southern California (65). It is harvested at several locations: along central California from Santa Cruz to Elkhorn Slough in Monterey Bay, and at Morro Bay and Pismo Beach; and along the southern coast at Hueneme, Zuma Beach, Santa Monica, Long Beach, Seal Beach, and Huntington Beach (65,84,156,179). Harvests along central California are intertidal, whereas further south Pismo clam is taken subtidally by divers at depths from the intertidal zone to 10 m. They are taken year-round, except in Santa Cruz and Monterey counties where the season is open from September to April (39). This species has a fine flavor and is eaten raw, fried, or in chowder, although some are also used for fish bait (65,84,179). In past years the Pismo clam was very abundant and in

one 2-1/2 month period, over 1,800 t were taken from a 6.4 m stretch of Pismo Beach (65).

Ecological--This species is a major infaunal suspension-feeder of the lower intertidal zone along central California and the inner sublittoral zone of southern California.

RANGE

Worldwide--The Pismo clam is a temperate, eastern Pacific species that is found from central California to Socorro Island, Mexico (about 450 km south of the southern tip of Baja California) (100).

Within Study Area--It ranges from Halfmoon Bay, California, to Magdalena Bay, Baja California Sur (65), and is abundant on the California beaches mentioned in the Recreational section.

LIFE MODE

Eggs and larvae are pelagic. Juveniles and adults are benthic infauna, seldom burrowing deeper than 21 cm (65).

HABITAT

Type--The eggs are neritic and the larvae neritic-oceanic. Juveniles and adults are found on high-energy beaches from the mid-intertidal zone to 25 m subtidally (84,91). Along central California they are most abundant at mean low tide line but in southern California they are found from the lower intertidal zone to 10 m (61,62,84,174).

Substrate--The eggs and larvae are found in the water column, whereas juveniles and adults occur on flat beaches of shifting sand (65,113).

Physical/Chemical--This species lives in euhaline waters of 8-24°C (23,61). It occurs primarily in areas of heavy surf and requires high dissolved oxygen concentrations (100,157).

MIGRATIONS AND MOVEMENTS

The larvae can potentially be dispersed by water currents as far as 64-161 km in 20 days, and apparently can be found far offshore since this species occurs at Socorro Island (62,100). Juveniles and adults remain in the same area for life.

POPULATION CHARACTERISTICS

Pismo clam can occur in densities of up to 984 adults per meter of shoreline (i.e., a l-m strip extending from the upper limit of the intertidal zone out to the area of breaking waves) (62).

REPRODUCTION

Mode--Sexual, separate sexes, oviparous (179).

Spawning--Reproduction can occur throughout the year, but takes place primarily between June and December (65,84) and is generally triggered by a rise in water temperature (179). During the spawning period, eggs and sperm are discharged from the exhalant siphons, and the release of sperm by an individual may trigger spawning for all other clams in a bed (62).

Fertilization--External, in the water column (65).

Reproductive Potential.--Fecundity increases with size, ranging from 15 millon eggs for a 76-mm female to 75 million for a female 122 mm in length (65,84). This species spawns 1-3 times annually and reproduces every year after reaching maturity (65,100).

GROWTH AND DEVELOPMENT

Egg Size--0.07 mm (84).

Embryonic Development--Indirect and external. The embryo quickly passes through several developmental stages and becomes a free-swimming trochophore larva in approximately 10-12 hours (160). The trochophore and veliger larvae are pelagic for 5-12 months before settling out of the water column (62,160).

Larval Size Range--0.07-2.38 mm (62,84).

Juvenile Size Range--2.4 mm to 25-51 mm (62).

Age and Size of Adults--This species matures between ages 1-3 years and has a shell size of 25-51 mm (62,65,84). It reaches legal size by age 7 years and may live up to 53 years (65,157). The Pismo clam has a max mum shell size of 190.5 mm and can weigh up to 1.8 kg (4).

FOOD AND FEEDING

Trophic Mode--Filter-feeder/suspension-feeder (65).

Food Items--The Pismo clam eats detritus, minute algae, and zooplankton (4,62,65,84,179).

Feeding Behavior--During feeding, water is sucked in through the inhalant siphon and expelled through the exhalant siphon (65). The inhalant siphon has cirri which prevent large particles from entering, and food particles are filtered by the gills (62,65). Feeding occurs only at the high tide period for intertidal clams (62). A 76-cm clam can filter 61 liters of water per day or 21,970 liters per year (65).

BIOLOGICAL INTERACTIONS

Predation--The larvae are eaten by planktivorous invertebrates and fishes (62). Juveniles and adults are eaten by moon snails, Cancer crabs, sharks,

rays, California corbina, shorebirds, gulls, and sea otters (84,157). This species burrows beneath the beach surface usually with the tip of the shell protruding (84); it burrows deeper in areas of heavy surf (157). The heavy shell also provides defense against many predators.

Competition--Undescribed. This species probably competes for space with other surf-dwelling clams where they co-occur (e.g., Pacific razor clam).

Symbiotic Relationships--A hydroid (Clytia bakeri) grows on the siphon and shell tip (61,84). Trematode parasites interfere with the clam's sexual development, but their presence in the Pismo clam meat is not harmful to man (65). Commensal mussel crabs live in the mantle cavity, and cyclopoid copepods live commensally on the gills (68,168).

Social Interactions--Undescribed.

Community Associations and Interactions--Undescribed.

FACTORS INFLUENCING POPULATIONS

Pismo clam successfully recruits to an area only every few years because of environmental conditions (65). Larval survival is influenced by several factors: they are eaten by planktivores, they are susceptible to temperature changes, and they may be swept either onto the beach with unfavorable substrate or offshore where they cannot settle out and survive (62). Juvenile and adult mortality occurs when they are dislodged during heavy storms and swept above the intertidal zone, ingest toxins from red tides, or are frozen in the intertidal zone during extremely cold weather (24,62). Sea otters and humans have drastically depleted populations on central California beaches (84).

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FAT GAPER CLAM OR HORSE CLAM, Tresus capax (Gould, 1850) (23)

(Alaskan gaper, blue clam, empire clam, gaper, gaper clam, greyneck clam, horseneck clam (6,84,123,134,168))

CLASSIFICATION

Phylum--Mollusca

Class--Bivalvia

Order--Veneroida

Family--Mactridae

MANAGEMENT

Because the fat gaper clam is a coastal species, it is not covered by federal fishery management plans in the United States. Its harvests are monitored by state fisheries agencies in Washington, Oregon, and California and by the Canada Department of Fisheries and Oceans in British Columbia (39,140,142,162,184).

Value

Commercial--This species and the very similar Pacific gaper clam, T. nuttalli, are known in commercial fisheries as the horse clam and separate harvests of these two species are undetermined. From British Columbia to northern California, these two clams are commercially harvested subtidally and intertidally with hydraulic pumps, mechanical dredges, potato forks, shovels, and clam rakes (43,44,45,160,162). In recent years (1981-83), harvests have averaged about 225 t (60% from Canada) annually, ranking them fifth in volume for the entire U.S.-Canada Pacific Coast clam harvest. Most are taken from four areas: the east coast of Vancouver Island between Oyster Bay and Qualicum Beach (this area produced 26% of the total 1981-83 catch); the Clayoquot Sound

region of the west coast of Vancouver Island (23% of total); Port Townsend and Admiralty Inlet at the mouth of Puget Sound (18%); and Coos Bay, Oregon (17%) (12,32,37,38,40,43,44,45,110,111,185). Horse clams are taken year-round (at least in British Columbia) but most harvests occur from July to December in British Columbia and Oregon. In recent yearsmost harvests in British Columbia have been taken by commercial and recreational geoduck divers after they have reached the geoduck quota (28).

Although the fat gaper clam has a very good taste and its meat is considered excellent for chowder stock or clam steaks, some characteristics tend to discourage its commercial harvest. This species burrows deep, making hand harvests difficult; it has a relatively fragile shell that tends to break; and it has valves that gape (hence the name), causing water loss and a reduced shelf life (160). Additionally, its meat yield is low (25-30% of total body weight is marketable), and the siphon (neck), which constitutes about 60% of its shucked weight, has a tough, leathery skin that requires considerable processing (151). Most of the catch is canned or used for crab bait (26,160).

Recreational--The fat gaper is harvested recreationally from Puget Sound, Washington, to Humboldt Bay, California (114,184). It is taken by hand or hand-powered equipment throughout the year in California but the seasons and locations vary in Washington and Oregon (39,142,184).

Ecological--From northern California to British Columbia, this species is an important suspension feeder on sandy mudflats.

RANGE

Worldwide--The fat gaper is a boreal, eastern Pacific species with a range that is entirely within the study area.

Within Study Area--This species ranges from Kodiak Island (western extreme) and the mouth of Prince William Sound in Alaska (northern extreme) to Monterey, California (5,21,23,129,137,143). It is most abundant in British Columbia, Washington, and Oregon (26,107).

LIFE MODE

Eggs and larvae are pelagic. Juveniles and adults are benthic infauna (84,113) and burrow to depths of perhaps 1 m, but usually 25-50 cm (74,115).

HABITAT

Type--The eggs and larvae are neritic, whereas the juveniles and adults are found from the middle intertidal zone (+2m) to depths of 30 m (21,23,84); adults are abundant to 5 m (in Washington) (77), but occur primarily in bays (84).

Substrate--Although this species usually occurs in gravel, it also occurs in fine sandy mud, mud with gravel and shell, and stiff clay (84,107,160,187).

Physical/Chemical--Fat gaper occurs in polyhaline-euhaline waters of 27-33 ppt (26,114). Fertilization can occur in the laboratory at 13-18°C; larvae survive at 5-18°C, but die at 20°C (26). Juveniles and adults survive in 2-20°C (23).

MIGRATIONS AND MOVEMENTS

The larvae are dispersed by the currents. Juveniles and adults do not move laterally during their lives (113).

POPULATION CHARACTERISTICS

Horse or gaper clams are found in densities of up to 200 clams per m^2 in northern Puget Sound (74), likely a mixture of both species. A standing stock

estimate for subtidal populations in Puget Sound in 1978 was 13,000 t. In that same year, major abundance areas were Agate Pass-Port Orchard (3,720t), Kilisut Harbor (2,500 t), Dungeness Spit (1,450 t), and Port Townsend Canal (950 t) (74). Estimates for other regions are unknown.

REPRODUCTION

Mode--Sexual, separate sexes, oviparous (26,114).

Spawning--Reproduction begins at the time of seasonal minimum water temperatures (26), usually in late winter to early spring. Timing varies by region (e.g., in British Columbia, spawning occurs from February to May, but primarily in March; in northern California, spawning occurs from January to March) (26,114).

Fertilization--External (113).

Reproductive Potential--Fecundity of this species is undescribed. Individuals may spawn repeatedly during a spawning season (26).

GROWTH AND DEVELOPMENT

Egg Size--0.06-0.07 mm (26).

Embryonic Development--Indirect and external (26). In laboratory studies, polar bodies develop within 40 minutes of fertilization. The duration of the larval stage varies with temperature (24 days at 15°C; 26 days at 10°C; 34 days at 5°C) (26). The larvae begin to settle out (i.e., crawling and swimming near the bottom) at a shell length of 0.23-0.25 mm (26).

Larval Size Range--0.06-0.07 mm to 0.26-0.28 mm (26).

Juvenile Size Range--0.26-0.28 mm to 60-69 mm (26).

Age and Size of Adults--Sexual maturity depends on size rather than age (26). Size at maturity is about 70 mm. This species attains maturity in 3 years in northern California, but it takes 4 years in British Columbia (26,187). Fat

gaper clam may live 16 years and reaches a shell length of 254 mm (26,123).

FOOD AND FEEDING

Trophic Mode--Filter-feeder/suspension-feeder (84).

Food Items--Juveniles and adults feed on suspended diatoms, flagellates, dinoflagellates, and fine detritus (84).

Feeding Behavior--Juveniles and adults have long siphons with separate, inhalant and exhalant tubes which extend from the body of the clam beneath the mud to the surface of the mud. Water is sucked into the inhalant siphon and flows continuously through the gills and out the exhalant tube (84). Food particles are filtered from the water by the gills and sorted by the palps (68). Feeding occurs at high tide in intertidal beds.

BIOLOGICAL INTERACTIONS

Predation--Juveniles are eaten by worms, snails, crustaceans, and copper rockfish (113,149). Adults are eaten by northern moon snail, Dungeness crab, pink seastars, and bat rays (187). Both juveniles and adults burrow and hence avoid many predators. Juveniles are active burrowers near the surface, but adults live as deep as 1 m beneath the surface and lose their ability to burrow (84,187).

Competition--The fat gaper clam may compete with T. nuttalli where their ranges overlap (e.g., southern British Columbia to northern California). It does not burrow as deeply as T. nuttalli and thus is more susceptible to freezing temperatures during low tides (84).

Symbiotic Relationships--The pea crab lives commensally in the mantle cavity of the fat gaper clam in and north of Humboldt Bay (68). The fat gaper is sometimes infected with haplosporidians and has parasitic cyclopoid copepods on its gills (17,168).

Community Associations and Interactions--Fat gaper commonly occurs with littleneck and butter clams (26,160).

FACTORS INFLUENCING POPULATIONS

There are no calculations of mortality rates from reliable field data for any bivalves in their natural environments. Mortality is likely highest during the larval stage, next highest during or just after settling, and gradually becomes less extensive as clams mature.

PACIFIC GAPER CLAM OR HORSE CLAM, Tresus nuttallii (Conrad, 1837)

(big-neck clam, blue clam, empire clam, gaper clam, great Washington clam, horseneck clam, otter-shell clam, rubberneck clam, summer clam (25,69,142,157,187))

CLASSIFICATION

Phylum--Mollusca

Class--Bivalvia

Order--Veneroida

Family--Mactridae (23,84)

MANAGEMENT

The Pacific gaper clam Is a coastal species that is not covered by federal fishery management plans in the United States. Its harvests are monitored by state fisheries agencies in Washington, Oregon, and California and by the Canada Department of Fisheries and Oceans in British Columbia (39,140,162,184,192).

VALUE

Commercial--This species and the very similar fat gaper clam, T. capax, are both known in commercial fisheries as horse clams; separate harvests of these two species are undetermined. These two clams are commercially harvested with hydraulic pumps or mechanical dredges in subtidal areas and with potato forks, shovels, and clam rakes in intertidal areas from British Columbia to northern California (160). In recent years (1981-83) their combined harvests have averaged about 225 t annually (60% from Canada), ranking them fifth in volume for the entire U.S.-Canada Pacific coast clam harvest. Most are taken in four areas: the east coast of Vancouver Island between Oyster Bay and Qualicum

Beach (26% of the total 1981-83 catch); the Clayoquot Sound region on the west coast of Vancouver Island (23% of total); Port Townsend and Admiralty Inlet at the mouth of Puget Sound (18%); and Coos Bay, Oregon (17%) (12,32,37,38,40,43, 44,45,110,111,182,183,185). The Pacific gaper clam is taken year-round in some areas, but most harvests occur from July to December in British Columbia and Oregon, and this species specifically is taken from September to April in northern California (Humboldt Bay) (32,44,45,140,162). In recent years, most harvests in British Columbia have been by geoduck divers after they reached the geoduck quota (28).

Although the Pacific gaper has a very good taste and its meat is considered excellent for chowder stock or clam steaks, some characteristics tend to discourage its commercial harvest. The Pacific gaper burrows deep, making hand harvests difficult; it has a relatively fragile shell that tends to break; and they have valves that gape (hence the name), causing water loss and a reduced shelf life (160). Additionally, its meat yield is low (less than 30% of total body weight is marketable) and the siphon which constitutes about 60% of its shucked weight has a tough, leathery skin that requires considerable effort to remove (151).

Recreational--The Pacific gaper is important from Puget Sound, Washington, to Morro Bay, California (65,192). Tomales Bay in California is likely the most important recreational harvest area--up to 35,000 individuals have been taken annually at one location in the bay (65). It is also harvested in other California areas such as Humboldt and Bodega Bays, Drakes Estero, Bolinas Lagoon, and Elkhorn Slough (65). This species is dug from substrate to depths of 1 m by hand or hand tools (39,65,184). Most Pacific gapers taken in the California recreational fishery are 3-8 years old (65). The siphon and other body parts are eaten (192).

Ecological--The Pacific gaper is possibly the most common clam along the entire California coast (65).

RANGE

Worldwide--This species is a temperate, amphi-North Pacific form that is found along the coasts of the Northwest and Northeast Pacific (23).

Within Study Area--It ranges from southeast Alaska (lat. 58°N) to Scammons Lagoon, Baja California Sur (23,84) and is apparently most common along the northern and central California coasts (107).

LIFE MODE

Pacific gaper eggs and larvae are pelagic. The juveniles and adults are benthic infauna (65) and burrow to depths of at least 1 m (usually 25-50 cm) (61,69,74,115).

HABITAT

Type--The eggs and larvae are neritic. Juveniles and adults are found from the lower intertidal zone to depths of over 30 m (65) and are abundant to 5 m (in Washington) (74). Their distribution is restricted to bays, estuaries, and sheltered areas along the coast (23,65,84).

Substrate--This species occurs in substrates of stiff clay, sandy mud, sand, and mud with gravel (84,107); it mostly occurs in fine sand or firm sandy mud (61,115,151).

Physical/Chemical--This species is found in polyhaline-euhaline waters with temperatures of 1-21°C (23).

MIGRATIONS AND MOVEMENTS

Larvae are dispersed by water currents. Juveniles and adults remain in the same area for life (113).

POPULATION CHARACTERISTICS

Gaper clams have been found in densities of up to 200 clams per m^2 in northern Puget Sound (probably T. capax) (74). Sizable aggregations may occur throughout its distribution, but, apart from those areas in California listed in the Recreational section, it is not possible to determine concentrations of Pacific gaper clam because it co-occurs with T. capax. In British Columbia, it may be found at localized sandy areas such as Rathtrevor Beach, Qualicum, and Clayoquot Sound (151). Specific areas of abundance in Oregon have included Tillamook, Netarts, Yaquina, and Coos Bays (much lesser amounts found in Alsea, Siuslaw, and Umpqua Bays) (115).

REPRODUCTION

Mode--Sexual, separate sexes, oviparous.

Spawning--Reproduction occurs during summer months throughout its range (65,74,151), but expands from spring to fall for California (65) and is year-round (mostly February-April) in central California (84).

Fertilization--External (113).

Reproductive Potential--Fecundity is undescribed. Individuals may spawn more than once during a spawning season, but this is doubtful for British Columbian waters (28).

Release of Young--Newly metamorphosed young occur year-round throughout its range; however, they occur in central California predominantly during the spring (84,113). This suggests that young may be released at other seasonally specific periods (e.g., summer) in localized areas throughout its range.

GROWTH AND DEVELOPMENT

Egg Size--Undescribed.

Embryonic Development--Indirect and external; details undescribed.

Larval Size Range--Undescribed, probably about 0.06-0.28 mm (26).

Juvenile Size Range--0.26 mm to 51.0-71.0 mm (26,65,84).

Age and Size of Adults--The Pacific gaper matures at age 2 years; shell length is about 51-70 mm (65,84). It lives to a maximum of 17 years and reaches a shell length of 200 mm (possibly 254 mm) (65,113,133). Maximum weight is about 1.8 kg (65).

FOOD AND FEEDING

Trophic Mode--Filter-feeder/suspension-feeder (113).

Food Items--This species feeds on detritus and plankton that probably include diatoms, flagellates, and dinoflagellates (65,84).

Feeding Behavior--Juveniles and adults have long siphons with separate inhalant and exhalant tubes which extend from the body up to the substrate surface. Water is sucked into the inhalant siphon and flows continuously through the gills and out the exhalant tube (5). Food particles are filtered from the water by the gills and are sorted by the palps (175). In intertidal beds, feeding occurs during high tide periods.

BIOLOGICAL INTERACTIONS

Predation--Juveniles are prey for snails, worms, crustaceans, and demersal fish (e.g., starry flounder) (84,113). The siphon tips are eaten by benthic feeding rays and flatfishes (24). Adults are eaten by northern moon snail, Dungeness crab, pink seastars, and leopard sharks (84,175). Juveniles and adults burrow and avoid many predators. Small juveniles are found near the substrate surface, whereas larger clams are active burrowers and may be found

deeper. Adults occur at least as deep as 1 m; clams <60 mm burrow slowly (84). Adults have their shells positioned in the sediment at an angle to their siphons and have leathery siphonal plates that protect the siphon tips from predators (84). If threatened, they retract their siphons, squirting water up to 1 m into the air when in the intertidal zone (61).

Competition--This species may compete with T. capax where their ranges overlap (e.g., southern British Columbia to northern California). It burrows more deeply than T. capax and, hence, is less susceptible to freezing temperatures during low tide periods (84).

Symbiotic Relationships--Epiphytic organisms such as red algae (Polysiphonia), hydroids, and barnacles grow on the siphonal plates (107). Pea crabs live commensally in the mantle cavity in areas south from Bodega Bay, California (68). Larval tapeworm (Echeneibothrium) cysts occur in the flesh of clams in California (cysts not harmful to man); cycloid copepods are found on the gills (84,168).

Community Associations and Interactions--This species occurs with littleneck, butter, and fat gaper clams in Puget Sound (84,160). Although found in the same locales as T. capax, their habitats differ. For example, in British Columbia this species is found in nearly pure sand substrate, whereas T. capax is found with littleneck and butter clams in gravel-shell soils (151).

FACTORS INFLUENCING POPULATIONS

There are no calculations of mortality rates from reliable field data for any bivalves in their natural environments. Mortality is likely highest during the larval stage, it is not as high during or just after settling, and it becomes gradually less extensive as clams mature (79).

WEATHERVANE SCALLOP, Patinopecten caurinus (Gould, 1850) (23)

(giant Pacific scallop, giant Pacific sea scallop, giant scallop, pecten, scallop (61,89,123))

CLASSIFICATION

Phylum--Mollusca

Class--Bivalvia

Order--Pterioida

Family--Pectinidae (8,23)

MANAGEMENT

The weathervane scallop resource usually occurs in or near state territorial seas and is managed by the states of Alaska, Washington, and Oregon. Harvests in British Columbia waters are monitored by the Canada Department of Fisheries and Oceans (11,140,142,180).

VALUE

Commercial--This species is harvested commercially by heavy metal dredges from the eastern Aleutian Islands in Alaska to southern Oregon (12,33,172). Since the inception of this fishery in the Northeast Pacific in 1967, over 75% of all harvests have come from Alaskan waters. In recent years (1981-83), however, substantial harvests also have been taken off Oregon (47% of coast-wide catch) (7,8,9,12,32,43,44,45,110,111,183).

Major fishing areas include: Albatross, Chiniak, and Portlock Banks off the east coast of Kodiak Island; the north coast of the Gulf of Alaska from Cape Saint Elias to Cape Fairweather; and off Tillamook Head and Coos Bay, Oregon. Additional harvest areas include several locations in Alaska from Umnak Island to southern Cook Inlet and in southeast Alaska, the southern

Strait of Georgia (British Columbia and Washington) and adjacent areas, and off the Pacific Northwest coast from Cape Elizabeth, Washington to the Oregon-California border (12,28,32,43,44,45,110,111,183). From 1981 to 1983, coastwide catches averaged 6,802 t (595 t of meats) with a value of $5 million to U.S. fishermen (99% of all catches were from U.S. waters). Although these amounts are relatively substantial, they represent less than 5% of the nationwide scallop harvest (and value) (126,127). [Authors' note: by 1985 most scallop fishing in Alaska had switched to new fishing grounds in the eastern Aleutian Islands (13,14).] During 1985 and 1986, an average of more than 200 t (meats) came from this region (14); however, these scallops are probably a species other than P. caurinus (104,143).)

Most fishing occurs at depths of 50-100 m and effort is targeted at 6- to 15-year-old scallops. Fishing success is highly dependent on periodic strong year classes; hence, harvest levels fluctuate widely (e.g., no catch in 1978 but 14,000 t in 1981). Harvests can occur year-round, but 90% of the catch off Oregon was taken between May and October, and much of the Alaska catch has been taken between March and June (8,9,10). Area restrictions have been established in parts of western Alaska to eliminate scallop dredging in red king crab habitat (14). Minimum ring sizes for dredges are employed -to reduce harvest of juvenile and young adult scallops (106).

Scallops do not keep well because they cannot close their valves (shell) tightly; hence, most are shucked and cleaned at sea (some are delivered in the shell in Oregon (173)). Only the large adductor muscle is retained, and it accounts for about 7-12% of the weight of a whole scallop (7% for Oregon and 12% for Alaska) (61,88,125). The meat has an excellent flavor and is usually sold frozen (61,125).

Recreational--This Is not an important recreation species.

Subsistence--Although not considered a staple for persons in remote areas of Alaska, there are small subsistence or "personal use" harvests of isolated stocks in southeast Alaska (Tenakee Inlet and near Wrangell) (106).

Ecological--This species is the largest scallop species in the world (125).

RANGE

Worldwide--This is a temperate, Northeast Pacific species with a worldwide range entirely within the region covered in the Data Atlas.

Within Study Area--It ranges from the eastern Bering Sea (south of about lat. 59°N) and the eastern Aleutian Islands to San Francisco, California (19,125). It is locally abundant off Kodiak Island, along the northeastern coast of the Gulf of Alaska, and off the Oregon coast (32,43,44,45,110,111).

LIFE MODE

Weathervane scallop eggs have not been observed. The larvae are planktonic initially, but later attach to a variety of sessile organisms with byssal threads. Juveniles and adults are benthic (motile and epibenthic) (125).

HABITAT

Type--Adults and juveniles occur sublittorally at depths of 2-200 m (21,23,125); however, most are found between 65 and 110 m (172,190). Larvae are neritic and probably occur over the continental shelf from the surface to 12 m (125).

Substrate--Juveniles and adults occur primarily on sandy bottoms, sometimes near rocky areas (28,104). Early stages of the larvae occur in the water column but later stages (spat) attach to bivalve shells, hydrozoans, bryozoans, kelp, and eelgrass on the bottom (125).

Physical/Chemical-- This species lives in euhaline waters of 28.0-33.9 ppt (90,98). Juveniles and adults occur in areas from 1 to 15°C, whereas larvae can survive at water temperatures to 16°C (23,98,139). Its benthic life stages cannot tolerate low oxygen environments or excessive silt (125).

MIGRATIONS AND MOVEMENTS

The larvae may undertake die1 vertical movements, ascending by night and descending by day (125). Although motile, adults do not migrate.

POPULATION CHARACTERISTICS

Undescribed.

REPRODUCTION

Mode--Sexual, separate sexes, oviparous (92,125).

Spawning--Reproduction occurs from February to October. Spawning begins in February off the Oregon coast, in May off the Washington coast, and in June further north (125,139,172). Spawning probably occurs throughout the adult range (21,23) and is initiated by a rapid rise in water temperature (125). During spawning, the weathervane scallop emits gametes in a steady stream or at intervals of one to several minutes by periodically clapping its valves (125).

Fertilization--External and probably occurs on or near the bottom at the time of spawning.

Reproductive Potential--This species probably spawns more than 100 million eggs per individual (161, but the number of spawnings per year or lifetime is unknown.

Release of Young--Larvae probably develop on the bottom throughout the adult depth range of 2-200 m (21,23,125).

GROWTH AND DEVELOPMENT

Egg size--0.06-.08 mm (98,125).

Embryonic Development--Indirect and external (125). Egg incubation lasts about 1 week (33). The trochophore and veliger larval stages are pelagic for 34-40 days and then settle to the bottom (90). The spat attach to a substrate, but juveniles later pull away and become motile (125).

Larval Size Range--About 0.06-0.24 mm (125).

Juvenile Size Range--4 to 65-99 mm (125,172).

Age and size of Adults--This species matures at age 3 years and at a size of 65-99 mm in length (92). Adults live up to 25 years and reach a maximum shell size of 280 mm (125).

FOOD AND FEEDING

Mode--Detritivore-nannoplanktivore (125).

Food Items--Larvae feed on planktonic algae (98), whereas juveniles and adults consume diatoms planktonic algae, protistans, spores, polychaetes, crustaceans, echinoderm larvae, and detritus (125).

Feeding Behavior--Weathervane scallops of all life stages are filter feeders, although detritus may be important to juveniles and adults (98).

BIOLOGICAL INTERACTIONS

Predation--A list of predators for weathervane scallop has not been documented. This species can sense predators with numerous well-developed eyes and tentacles (capable of detecting odors and water movements) along the edge of the mantle (4). In addition, its shell protects it from many predators.

Competition--Weathervane scallop may compete for food with suspension-feeding organisms that grow on its shells (125).

Symbiotic Relationships--Many organisms live on its shell, including algae, boring and other sponges, hydroids, sea anemones, tubicolous and boring polychaetes, limpets, oysters, barnacles, branching and encrusting bryozoans, and ascidians (90,172). Sponge encrustation often repels seastars. Nematodes are sometimes found in the adductor muscles (125).

Community Associations and Interactions--Undescribed.

FACTORS INFLUENCING POPULATIONS

Cold water temperatures may increase the duration of the pelagic larval phase and hence increase larval mortality (125). Circulation patterns largely determine where a benthic population will develop (172). Spat are susceptible to low salinity and oxygen levels, high and low temperatures, and silting (125). Warm or cold temperatures may kill adults, and adult mortality may be affected by shell encrustation. Fouling organisms can increase shell weight, thereby allowing a greater susceptibility to predation by decreasing adult mobility. These organisms may also inhibit opening and closing of the valves. Boring sponges and polychaetes decrease the growth of scallops. Additionally, scallop dredge operations often kill individuals that are run over by the dredge (19).

ACKNOWLEDGEMENTS

We wish to express our sincere appreciation to the numerous scientists who reviewed these synopses. Those persons include: Neil Bourne (reviewer for Pacific oyster, and Pacific littleneck, Manila, and gaper clams) and Glenn Jamieson (weathervane scallop) with the Canada Department of Fisheries and Oceans Pacific Biological Station, Nanaimo, British Columbia; John Hilsinger (razor clam and weathervane scallop) from the Alaska Department of Fish and Game (ADF&G), Anchorage, and Tim Koeneman (geoduck, razor clam, and weathervane scallop), ADF&G, Petersburg, Alaska; Lynn Goodwin (geoduck and gaper clam) with the Washington Department of Fisheries (WDF) Shellfish Laboratory, Brinnon, Washington, Eric Hurlburt (Pacific oyster and Pacific littleneck and Manila clams), WDF, Olympia, and Doug Simons (razor clam) WDF, Montesano, Washington; Rick Starr (weathervane scallop) from the Oregon Department of Fisheries and Wildlife, Newport, Oregon; and Eric Knaggs (California jackknife clam), David Parker (all abalones) and John Sunada (Pismo clam) with the California Department of Fish and Game, Long Beach, California.

Special thanks are expressed to Professor Dewey Schrout of Jarvis Christian College, Jarvis, Texas. Dr. Schrout, participant in the NWAFC's Minority College Professors Summer Employment Program in 1986, compiled a glossary for the entire living marine resource section of the West Coast Data Atlas. Our glossary is a portion of that manuscript.

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REFERENCES

1 Aasen, K. D. 1967. Summary of the 1963 and 1964 southern California inshore bait fishery. Calif. Fish Game 53(1):28-34.

2 Abbott, D. P., and E. C. Haderlie. 1980. Prosobranchia: Marine snails. In R. H. Morris, D. P. Abbott, and E. C. Haderlie (editors), Intertidal invertebrates of California, p. 230-307. Stanford Univ. Press, Stanford, CA.

3 Abbott, D. P., and D. J. Reish. 1980. Polychaeta: The marine annelid worms. In R. H. Morris, D. P. Abbott, and E. C. Haderlie (editors), Intertidal invertebrates of California, p. 448-489. Stanford Univ. Press, Stanford, CA.

4 Abbott, R. T., H. S. Zim, and G. F. Sandstrom. 1968. Seashells of North America. Golden Press, New York, 280 p.

5 Abbott, R. T. 1974. American Seashells: The marine mol lusca of the Atlantic and Pacific coasts of North America, 2nd edition. Van Nostrand Reinhold Co., New York, 663 p.

6 Abbott, R. T., and S. P. Dance. 1982. Compendium of seashells. D. P. Dutton, Inc., New York, 411 p.

7 Alaska Department of Fish and Game. 1984. Alaska 1976 catch and production. Statistical Leaf. No. 29, 63 p. Alaska Dep. Fish and Game, Comm. Fish. Stat., P.O. Box 3-2000, Juneau, AK 99802.

8 Alaska Department of Fish and Game. 1984. Alaska 1980 catch and production. Statistical Leaf. No. 33, 63 p. Alaska Dep. Fish and Game, Comm. Fish. Stat., P.O. Box 3-2000, Juneau, AK 99802.

9 Alaska Department of Fish and Game. 1984. Alaska 1981 catch and production. Statistical Leaf. No. 34, 63 p. Alaska Dep. Fish and Game, Comm. Fish. Stat., P.O. Box 3-2000, Juneau, AK 99802.

10 Alaska Department of Fish and Game. 1984. Alaska 1983 catch and production. Statistical Leaf. No. 36, 64 p. Alaska Dep. Fish and Game, Comm. Fish. Stat., P.O. Box 3-2000, Juneau, AK 99802.

11 Alaska Department of Fish and Game. 1984. 1984 commercial shellfish regulations. 115 p. Alaska Dep. Fish and Game, P.O. Box 3-2000, Juneau, AK 99802.

12 Alaska Department of Fish and Game. 1985. 1981-1983 commercial shellfish statistics by statistical subarea. Computer printout compiled and provided by Carmine DiCostanzo, Chief, Computer Services Section. Alaska Dep. Fish and Game, P.O. Box 3-2000, Juneau, AK 99802.

13 Alaska Department of Fish and Game. 1986. Alaska 1985 catch and production. Statistical Leaf. No. 38, 61 p. Alaska Dep. Fish and Game, Comm. Fish. Stat., P.O. Box 3-2000, Juneau, AK 99802.

14 Alaska Department Fish and Game. 1987. Westward region shellfish report to the Alaska Board of Fisheries. 317 p. Alaska Dep. Fish and

Game, Comm. Fish. Div., Westward Regional Office, P.O Box 686, Kodiak, AK 99165.

15 Anderson, A. M., Jr. 1971. Spawning, growth, and spatial distribution of the geoduck clam, Panope generosa, Gould, in Hood Canal, Washington. Ph.D. Thesis, Univ. Wash., Seattle, WA, 133 p.

16 Antonelis, G., Northw. Alaska Fish. Ctr., 7600 Sand Point Way NE, Seattle, WA 98115. Pers. commun., September and November 1985.

17 Armstrong, D. A., and J. L. Armstrong. 1974. A haplosporidian infection in gaper clams, Tresus capax (Gould) from Yaquina Bay, Oregon. Proc. Natl. Shellfish. Assoc. 64:68-72.

18 Barnes, R. S. K. 1984. Kingdom Animalia. In R. S. K. Barnes (editor), A synoptic classification of living organisms, p. 129-257. Sinauer Assoc., Inc., Publ., Sanderland, MA, 262 p.

19 Barr, L., and N. Barr. 1983. Under Alaskan seas. Alaska Northwest Publ. Co., Anchorage, AK, 208 p.

20 Barrett, E. M. 1963. The California oyster industry. Calif. Dep. Fish Game Fish Bull. 123, 103 p.

21 Baxter, R. 1983. Mollusks of Alaska. 77 p. Alaska Dep. Fish and Game, P.O. Box 90, Bethel, AK 99559-9990.

22 Berg, C. J., Jr. 1971. A review of possible causes of mortality of oyster larvae of the genus Crassostrea in Tomales Bay, California. Calif. Fish Game 57(1):69-75.

23 Bernard, F. R. 1983. Catalogue of the living Bivalvia of the eastern Pacific Ocean: Bering Strait to Cape Horn. Can. Spec. Fish. Aquat. Sci. 61, 102 p.

24 Bonnot, P. 1940. The edible bivalves of California. Calif. Fish Game 26(3):212-237.

25 Boulding, E. G., and T. K. Hay. 1984. Crab response to prey density can result in density-dependent mortality of clams. Can. J. Fish. Aquat. Sci. 41:521-525.

26 Bourne, N., and D. W. Smith. 1972. The effect of temperature on the larval development of the horse clam, Tresus capax (Gould). Proc. Natl. Shellfish. Assoc. 62:35-37.

27 Bourne, N. 1982. Distribution, reproduction, and growth of Manila clam, Tapes philippinarum (Adams and Reeves) in British Columbia. J. Shellfish Res. 2(1):47-54.

28 Bourne, N., Canada Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C. V9R5K6. Pers. commun., April 1988.

29 Breen, P. A. 1980. Measuring fishing intensity and annual production in the abalone fishery of British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. No. 947, 49 p.

30 Breen, P. A., and T. L. Shields. 1983. Age and size structure of five populations of geoduc clams (Panope generosa) in British Columbia Can. Tech. Rep. Fish. Aquat. Sci. 1169, 62 p.

31 Breese, W. P., and A. Robinson. 1981. Razor clams, Siligua patula (Dixon): gonadal development,induced spawning and larval rearing. Aquaculture 22:27-33.

32 Brown, K., R. Berry, J. Lukas, and C. Carter. 1984. 1981 pounds and value of commercially caught fish and shellfish landed in Oregon. 54 p. Ore. Dep. Fish and Game, Marine Science Drive, Bldg. 3, Portland, OR 977365.

33 Browning, R. J. 1980. Fisheries of the North Pacific. Revised edition. Alaska Northwest Publ. Co., Anchorage, AK, 423 p.

34 Burge, R., S. Schultz, and M. Odemar. 1975. Draft report on recent abalone research in California with recommendations for management. 62 p. Calif. Dep. Fish and Game, 245 W. Broadway, Suite 350, Long Beach, CA 90802.

35 Burge, R. T., and S. A. Schultz. 1973. The marine environment in the vicinity of Diablo Cove with special reference to abalones and bony fishes. Mar. Resources Tech. Rep. No. 19, 433 p. Calif.

Dep. Fish and Game, 245 W. Broadway, Suite 350, Long Beach, CA 90802.

36 California Department of Fish and Game. 1982. A review of some California fisheries for 1980 and 1981. Calif. Coop. Oceanic Fish. Invest. Rep. 23:8-14.

37 California Department of Fish and Game. 1982. California commercial fish landings by region - December, 1981 (preliminary). A computer printout from Calif. Dep. Fish and Game. March 25, 1982, 2p. Available from 1416 Ninth St., Sacramento, CA 95814.

38 California Department of Fish and Game. 1983. California commercial fish landings by region - December, 1982 (preliminary). A computer printout from Calif. Dep. Fish and Game, February 6, 1983, 2 p. Available from 1416 Ninth St., Sacramento, CA 95814.

39 California Department of Fish and Game. 1984. California sport-fishing regulations 1984: A summary. Calif. Dep. Fish and Game, 1416 Ninth St., Sacramento, CA 95184.

40 California Department of Fish and Game. 1984. California commercial fish landings by region - December, 1983 (preliminary). A computer printout from Calif. Dep. Fish and Game, February 10, 1984, 2 p. Available from 1416 Ninth St., Sacramento, CA 95814.

41 California Department of Fish and Game. 1985. Review of some California fisheries for 1984. Calif. Coop. Oceanic Fish. Invest. Rep. 26:9-16.

42 California Department of Fish and Game. 1985. California commercial abalone landings and values. Provided in table form by Steve Koplin, Marketing and Statistics, Southwest Regional Office, Natl. Mar. Fish. Serv., 300 S. Ferry St., Terminal Island, CA 90731.

43 Canada Department of Fisheries and Oceans. 1982. British Columbia catch statistics by area and type of gear for 1981. Can. Dep. Fish. Oceans, Pacific Region, 1090 W. Pender St., Vancouver, B.C., V6E2P1, 223 p.

44 Canada Department of Fisheries and Oceans. 1983. British Columbia catch statistics by area and type of gear for 1982. Can. Dep. Fish. Oceans, Pacific Region, 1090 W. Pender St., Vancouver, B.C., V6E2P1, 223 p.

45 Canada Department of Fisheries and Oceans. 1985. British Columbia catch statistics by area and type of gear for 1983. Can. Dep. Fish. and Oceans, Pacific Region, 1090 W. Pender St., Vancouver, B.C., V6E2P1, 239 p.

46 Chew, K. K., College of Fisheries, WH 10, Univ. of Washington, Seattle, WA. Pers. commun., March 1988.

47 Coan, E. 1973. The northwest American Psammobiidae. Veliger 16:40-57.

48 Collins, R., California Department of Fish and Game, 245 W. Broadway, Long Beach, CA 90802. Pers. commun., March 1988.

49 Cox, K. W. 1962. California abalones, family Haliotidae. Calif. Dep. Fish Game Fish Bull. 118, 133 p.

50 Crane, J. M., Jr., L. G. Allen, and C. Eisenmann. 1975. Growth rate, distribution, and population density of the northern quahog, Mercenaria mercenaria in Long Beach, California. Calif. Fish Game 61(2):68-81.

51 Dall, W. H. 1921. Summary of the marine shellbearing mollusks of the Northwest Coast of America, from San Diego, California to the Polar Sea, mostly contained in the collection of the United States National Museum, with illustrations of hitherto unfigured species. U.S. Natl. Mus. Bull. 122, 217 p.

52 Direction General de Informatica y Estadistica, Secretaria de Pesca, Mexico. 1982.. Anuario estadistico de pesca 1981. Direccion General de Informatica y Estadistica, Secretaria de Pesca, Mexico, D.F., 796 p.

53 Direccion General de Informatica y Estadistica, Secretaria de Pesca, Mexico. 1984. Anuario estadistico de pesca 1982. Direccion General de Informatica y Estadistica, Secretaria de Pesca, Mexico, D.F., 513 p.

54 Direccion General de Informatica y Estadistica, Secretaria de Pesca, Mexico. 1985. Anuario estadistico de pesca, 1983. Direccion

General de Informatica y Estadistica, Secretaria de Pesca, Mexico, D.F., 327 p.

55 Duffy, J., California Department of Fish and Game, San Diego, CA. Pers. commun., March 31, 1987.

56 Eber, L. E. 1977. Contoured depth-time charts (0-200 m, 1950-1966) of temperature, salinity, oxygen and sigma-t at 23 CalCOFI stations in the California current. Calif. Coop. Ocean. Fish. Invest. Atlas (25):231.

57 Elston, R. A. 1986. An intranuclear pathogen [nuclear inclusion "X" (NIX)] associated with massive mortalities of the Pacific razor clam, Siligua patula. J. Invert. Pathol. 47(1):93-104.

58 Faudskar, J., Oregon State University extension agent, Oregon State University, Department of Fish and Wildlife, 104 Nash Hall, Corvallis, OR 97331. Pers. commun., March 1988.

59 Feder, H. M. 1980. Asteroidea: The seastars. In R. H. Morris, D. P. Abbott, and E. C. Haderlie (editors), Intertidal invertebrates of California, p. 117-135. Stanford Univ. Press, Stanford, CA.

60 Feder, H. M., and A. J. Paul. 1973. Abundance estimations and growth-rate comparisons for the clam Protothaca staminea from three beaches in Prince William Sound, Alaska, with additional comments on size-weight relationships, harvesting and marketing. IMS Tech. Rep. R73-3, 34 p. Inst. Mar. Sci., Univ. Alaska, Fairbanks, AK.

61 Fitch, J. E. 1953. Common marine bivalves of California. Calif. Dep. Fish Game Fish Bull. 90, 102 p.

62 Fitch, J. E. 1961. The Pismo clam. Calif. Dep. Fish and Game, 1416 Ninth St., Sacramento, CA 95814, 22 p.

64 Frey, H. W., California Department Fish and Game, 245 West Broadway, Long Beach, CA 90802. Pers. commun., February 1987.

65 Frey, H. W. (editor). 1971. California's living marine resources and their utilization. Calif. Dep. Fish and-Game, Sacramento, CA, 148 p.

66 Frey, H. W., California Department Fish and Game, Long Beach, CA. Pers. commun., September 1985.

67 Gallucci, V. F., and R. K. Kawaratani. 1975. Mortality of Transennella tantilla due to burial. J. Fish. Res. Board Can. 32:11637-1640.

68 Garth, J. S., and D. P. Abbott. 1980. Brachyura: The true crabs. In R. H. Morris, D. P. Abbott, and E. C. Haderlie (editors), Intertidal invertebrates of California, p. 594-630. Stanford Univ. Press, Stanford, CA.

69 Gates, D. E., and H. W. Frey. 1974. Designated common names of certain marine organisms of California. Calif. Dep. Fish Game Fish Bull. (161):55-90.

70 Giorgi, A. E., and J. D. DeMartini. 1977. A study of the reproductive biology of the red abalone, Haliotis rufescens Swainson, near Mendocino, California. Calif. Fish Game 63(2):80-94.

71 Glock, J. W., and K. K. Chew. 1979. Growth, recovery, and movement of Manila clams, Venerupis japonica (Deshayes) at Squaxin Island, Washington. Proc. Natl. Shellfish. Assoc. 69:15-20.

72 Goodwin, C. L. 1973. Distribution and abundance of subtidal hard-shell clams in Puget Sound, Washington. Wash. Dep. Fish. Tech. Rep. 14, 81 p.

73 Goodwin, C. L. 1975. Observations on spawning and growth of subtidal geoducks (Panope generosa, Gould). Proc. Natl. Shellfish. Assoc. 65: 49-58.

74 Goodwin, L. 1971. Clams of Puget Sound, 8 p. Wash. Dep. Fish., Mailstop AX 11, Olympia, WA 98504.

75 Goodwin, L. 1973. Effects of salinity and temperature on the embryos of the geoduck clam (Panope generosa Gould). Proc. Natl. Shellfish Assoc. 63:93-95.

76 Goodwin, L. 1973. Subtidal geoducks of Puget Sound, Washington. Wash. Dep. Fish. Tech. Rep. 13, 64 p.

77 Goodwin, L., and W. Shaul. 1978. Puget Sound subtidal hardshell clam survey data. Wash. Dep. Fish. Prog. Rep. 44, 92 p.

78 Goodwin, L., W. Shaul, and C. Budd. 1979. Larval development of the geoduck clam (Panope generosa, Gould). Proc. Natl. Shellfish. Assoc. 69:73-76.

79 Goodwin, L., Washington Department of Fisheries, Brinnon, WA. Pers. commun., June 1987.

80 Goodwin, L., and B. Pease. 1987. The distribution of geoduck (Panope abrupta) size, density, and quality in relation to habitat characteristics such as geographic area, water depth, sediment type, and associated flora and fauna in Puget Sound, Washington. Wash. Dep. Fish. Tech. Rep. 102, 44 p.

81 Gotshall, D. W. 1977. Stomach contents of northern California Dungeness crabs, Cancer masister. Calif. Fish Game 63(1):43-51.

82 Grossman, G. D. 1979. Symbiotic burrow-occupying behavior in the bay goby, Lepidogobius lepidus. Calif. Fish Game 65(2):122-124.

83 Haaker, P. L., K. C. Henderson, and D. O. Parker. 1986. California abalone. Mar. Res. Leaflet, Calif. Dep. Fish and Game, Long Beach, CA, No. 11, 16 p.

84 Haderlie, E. C., and D. P. Abbott. 1980. Bivalvia: The clams and allies. In R. H. Morris, D. P. Abbott, and E. C. Haderlie (editors), Intertidal invertebrates of California, p. 355-411. Stanford Univ. Press, Stanford, CA.

85 Harbo, R. M., and S. D. Peacock. 1983. The commercial geoduck clam fishery in British Columbia, 1976 to 1981. Can. Manuscr. Rep. Fish. Aquat. Sci. 1712, 40 p.

86 Haro, B. H., E. P. Nunez, A. F. Mattus, and M. A. Landin. 1981. The development and perspective of oyster culture in Mexico. In K. K. Chew (editor), Proceedings of the North American oyster workshop, p. 64-69. Louisiana State Univ., Baton Rouge, LA, 300 p.

87 Haydock, C. I. 1964. An experimental study to control oyster drills in Tomales Bay, California. Calif. Fish Game 50(1):11-28.

88 Haynes, E. B., and G. C. Powell. 1968. Preliminary report on the Alaska sea scallop: fishery exploration, biology, and commercial processing. Alaska Dep. Fish and Game Info. Leaf. 125, 20 p.

89 Haynes, E. B., and J. C. McMullen. 1970. Relation between meat weight and shell weight of the giant Pacific sea scallop, Patinopecten caurinus, from the Gulf of Alaska. Proc. Natl. Shellfish. Assoc. 60:50-53.

90 Haynes, E. B., and C. R. Hitz. 1971. Age and growth of the giant Pacific sea scallop, Patinopecten caurinus, from the Strait of Georgia and outer Washington coast. J. Fish. Res. Board Can. 28:1335-1341.

91 Hedgepeth, J. W., and S. Hinton. 1961. Common seashore life of southern California. Naturegraph Co., Healdsburg, CA, 65 p.

92 Hennick, D. P. 1970. Reproductive cycle, size at maturity, and sexual composition of commercially harvested weathervane scallops (Patinopecten caurinus) in Alaska. J. Fish Res. Board Can. 27:2112-2119.

93 Hochberg, F. G., Jr., and W. G. Fields. 1980. Cephalopoda: The squids and octopuses. In R. H. Morris', D. P. Abbott, and E. C. Haderlie (editors), Intertidal invertebrates of California, p. 429-444. Stanford Univ. Press, Stanford, CA.

94 Holland, D. A., and K. K. Chew. 1974. Reproductive cycle of the Manila clam (Venerupis japonica), from Hood Canal, Washington. Proc. Natl. Shellfish. Assoc. 64:53-58.

95 Hurlburt, E., Washington Department of Fisheries, Mailstop AX 11, Olympia, WA 98504. Pers. commun., March 1988.

96 Ingraham, W. J., Jr. 1967. The geotrophic circulation and distribution of water properties off the coasts of Vancouver Island and Washington, spring and fall 1983. Fish. Bull., U.S. 66(2):223-250.

97 Islas-Olivares, R. 1975. El ostion japones (Crassostrea gigas) en Baja California. [In Spanish] Ciencias Marinas 2(1):58-89.

98 Jamieson, G. S., Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C. Pers. commun., June 1987.

99 Jamison, D., R. Heggen, and J. Lukes. 1984. Underwater video in a regional benthos survey. In Proceedings of the Pacific Congress on Marine Technology. Marine Technology Society, Honolulu, HA 96822.

100 Johnson, M. E., and H. J. Snook. 1927. Seashore animals of the Pacific coast. Dover Publ., New York, 659 p.

101 Keen, A. M., and E. Coan. 1974. Marine molluscan genera of western North America: An illustrated key, 2nd edition. Stanford Univ. Press, Stanford, CA, 208 p.

102 Keep, J. 1935. West coast shells. Stanford Univ. Press, Stanford, CA, 350 p.

103 Kessler, D. W. 1985. Alaska's saltwater fishes and other sea life. Alaska Northwest Publ. Co., Anchorage, AK, 358 p.

104 Kessler, D. W., NMFS, Northwest and Alaska Fisheries Center, 7600 Sand Point Way NE, Seattle, WA 98115. Pers. commun., May 1987.

105 Koeneman, T. 1987. Statistical Area A (Southeast Alaska - Yakutat) miscellaneous species report to Alaska Board of Fisheries, Section 6.0. In Shellfish Report to the Alaska Board of Fisheries 1986/1987. Alaska Dep. Fish and Game, Com. Fish. Div., Petersburg, AK 99833.

106 Koeneman, T., Alaska Department of Fish and Game, Petersburg, AK. Pers. commun., December 1987.

107 Kozloff, E. N. 1983. Seashore life of the northern Pacific coast. Univ. Washington Press, Seattle, WA, 370 p.

108 Kuroda, T., T. Habe, and K. Oyama. 1971. The seashells of Sagami Bay. Maruzen Co., Ltd., Tokyo, 487 p.

109 Lee, K. W. F., J. S. Corbin, and W. A. Brewer. 1981. Overview of oyster culture in Hawaii and various U. S. Pacific island territories. In K. K. Chew (editor), Proceedings of the North American oyster workshop, p. 70-85. Louisiana State Univ., Baton Rouge, LA, 300 p.

110 Lucas, J., and C. Carter. 1984. 1982 pounds and value of commercially caught fish and shellfish landed in Oregon. 52 p. Oreg. Dep. Fish and Wildl., P.O. Box 3503, Portland, OR 97207.

111 Lucas, J., and C. Carter. 1985. 1983 pounds and value of commercially caught fish and shellfish landed in Oregon. 70 p. Oreg. Dep. Fish and Wildl., P.O. Box 3503, Portland, OR 97207.

112 Maaker, P. L., K. C. Henderson, and D. O. Parker. 1986. California abalone. Mar. Res. Leaflet, Calif. Dep. Fish and Game, Long Beach, CA, No. 11, 16 p.

113 MacGinitie, G. E., and N. MacGinitie. 1949. Natural history of marine animals. McGraw-Hill Book Co., Inc., New York, 473 p.

114 Machell, J. R., and J. D. DeMartini. 1971. An annual reproductive cycle of the gaper clam, Tresus capax (Gould), in South Humboldt Bay, California. Calif. Fish Game 57(4):274-282.

115 Marriage, L. D. 1958. The bay clams of Oregon: their identification, relative abundance, and general distribution. Fish. Comm. Oreg., Ed. Bull. 2, 29 p.

116 Matsen, B. 1986. Ocean Pacer ready to hit Aleutian scallop grounds. Natl. Fisherman 66(10):42-44.

117 McAllister, R. 1975. California marine fish landings for 1975. Calif. Dep. Fish Game Fish Bull. 163, 53 p.

118 McAllister, R. 1976. California marine fish landings for 1974. Calif. Dep. Fish Game Fish Bull. 166, 53 p.

119 McLean, J. H. 1969. Marine shells of southern California. Los Angeles County Museum of Natural History, Sec. Ser. 24, Zool. 11, 104 p.

120 McLean, J. H., Los Angeles County Museum of Natural History, Los Angeles, CA. Pers. commun., March 30, 1987.

121 Menzel, R. W. 1974. Portuguese and Japanese oysters are the same species. J. Fish. Res. Board Can. 31:453-456.

122 Morado, F., NMFS, Northwest and Alaska Fisheries Center, 7600 Sand Point Way NE, Seattle, WA 98115. Pers. commun., March 1988.

123 Morris, P. A. 1966. A field guide to Pacific Coast shells. Houghton-Mifflin Co., Boston, MA, 297 p.

124 Mottet, M. G. 1978. A review of the fishery biology of abalones. Wash. State Dep. Fish. Tech. Rep. No. 37, 81 p.

125 Mottet, M. G. 1979. A review of the fishery biology and culture of scallops. Wash. State Dep. Fish. Tech. Rep. No. 39, 100 p.

126 National Marine Fisheries Service. 1983. Fisheries Statistics of the United States, 1982. U.S. Dep. Commer., Natl. Ocean. Atmos. Admin., Natl. Mar. Fish. Serv., Cur. Fish. Stat. No. 8300, 117 p.

127 National Marine Fisheries Service. 1984. Fisheries Statistics of the United States, 1983. U.S. Dep. Commer., Natl. Ocean. Atmos. Admin., Natl. Mar. Fish. Serv., Cur. Fish. Stat. No. 8320, 121 p.

128 National Marine Fisheries Service. 1985. Imports of abalone into the United States. NOAA, NMFS, Office of Data and Information Management, Washington, D.C. Provided in table form by Steve Koplin, Marketing and Statistics, Southwest Regional Office, Natl., Mar. Fish. Serv., Terminal Island, CA 90731.

129 Nickerson, R. B. 1975. A critical analysis of some razor clam (Siligua patula Dixon) populations in Alaska. 194 p.Alaska Dep. Fish and

Game, Div. of Fish. Rehab., Enhancement and Development, P.O. Box 3-2000, Juneau, AK 99802.

130 Nickerson, R. B. 1977. A study of the littleneck clam (Protothaca staminea Conrad) and the butter clam (Saxidomus giganteus Deshayes) in a habitat permitting coexistence, Prince William Sound, Alaska. Proc. Natl. Shellfish. Assoc. 67:85-102.

131 Noel, D., California Department of Fish and Game, 1416 Ninth Street, Sacramento, CA 95814. Pers. commun., March 1988.

132 North Pacific Fishery Management Council. 1984. Fishery management plan for the Gulf of Alaska groundfish fishery. North Pac. Fish. Manage. Council, 605 West 4th, Suite 306, Anchorage, AK 99510.

133 North, W. J. 1976. Underwater California. Univ. Calif. Press, Berkeley, CA, 276 p.

134 Northwest and Alaska Fisheries Center. 1985. Species code book, January 1985. U.S. Dep. Commer., Natl. Ocean. Atmos. Admin., Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle, WA 98115, 112 p.

135 Nosho, T. Y. 1972. The clam fishery of the Gulf of Alaska. In D. H. Rosenberg (editor), A review of the oceanography and renewable resources of the northern Gulf of Alaska. Univ. Alaska, Inst. Mar. Sci. Tech. Rep. R72-23, 690 p.

136 Nosho, T. Y., and K. K. Chew. 1972. The settling and growth of the Manila clam, Venerupis japonica (Deshayes), in Hood Canal, Washington. Proc. Natl. Shellfish Assoc. 62:50-58.

137 Oldroyd, I. S. 1924. The marine shells of the West Coast of North America. Stanford Univ. Publ. Geol. Sci. 1(1):247 p.

138 Oliphant, M. S. 1979. California marine fish landings for 1976. Calif. Dep. Fish Game Fish Bull. 170, 56 p.

139 Olsen, S. 1981. New candidates with aquaculture potential in Washington State: Pinto abalone (Haliotis kamtschatkana), weathervane (Pecten caurinus), and purple-hinge rock scallop (Hinnites multirugosus). J. Shellfish Res. 1(1):133.

140 Oregon Department of Fish and Wildlife. 1984. 1984 synopsis, Oregon commercial fishing regulations. Oreg. Dep. Fish and Wildl., Portland, OR, 20 p.

141 Oregon Department of Fish and Wildlife. 1984. Shellfish Investigations 1974-1983. Oreg. Dep. Fish and Wildl. 1984 Prog. Rep., 22 p.

142 Oregon Department of Fish and Wildlife. 1984. 1984 and 1985 Oregon sportfishing regulations for fish, shellfish, and marine invertebrates. Oreg. Dep. Fish and Wildl., Portland, OR, 32 p.

143 Otto, R. S., Director, NMFS, Northwest and Alaska Fisheries Center, Kodiak Facility, P.O. Box 1638, Kodiak, AK 99615. Pers. commun., April 1987.

144 Parker, D. O., California Department of Fish and Game, Long Beach, CA. Pers. commun., February 1987.

145 Paul, A. J., and H. M. Feder. 1976. Clam, mussel and oyster resources of Alaska. Inst. Mar. Sci., Univ. Alaska, Fairbanks, AK, Sea Grant Report No. 76-6, 41 p.

146 Peterson, C. H. 1982. The importance of predation and intra- and interspecific competition in the population biology of two infaunal suspension-feeding bivalves, Protothaca staminea and Chione undatella. Ecol. Monogr. 52:437-475.

147 Pinkas, L. 1974. California marine fish landings for 1972. Calif. Dep. Fish Game Fish Bull. 161:4-53.

148 Pinkas, L. 1977. California marine fish landings for 1975. Calif. Dep. Fish Game Fish Bull. 168, 55 p.

149 Prince, E. D., and D. W. Gotshall. 1976. Food of the copper rockfish, Sebastes caurinus Richardson, associated with an artificial reef in South Humboldt Bay, CA. Calif. Fish Game 62(4):274-285.

150 Province of British Columbia. 1985. Fisheries production statistics of British Columbia, 1984. Fisheries Branch, Ministry of

Environment, Province of British Columbia. 46 p.

151 Quale, E. B., and N. Bourne. 1972. The clam fisheries in British Columbia. Fish. Res. Board Can. Bull. 179, 71 p.

152 Quayle, D. B. 1960. The intertidal bivalves of British Columbia. British Columbia Provincial Museum, Victoria, B.C., Handbook 17:1-104.

153 Quayle, D. B. 1969. Paralytic shellfish poisoning in British Columbia. Fish. Res. Board Can. Bull. 168, 68 p.

154 Quayle, D. B. 1969. Pacific oyster culture in British Columbia. Fish. Res. Board Can. Bull. 169, 192 p.

155 Quayle, D. B. 1971. Growth, morphometry, and breeding in the British Columbia abalone (Haliotis kamtschatkana Jonas). Fish. Res. Board Can. Tech. Rep. 279, 83 p.

156 Reish, D. J. 1972. Marine life of southern California. Available from Donald J. Reish, 3092 Blume Dr., Los Alamitos, CA 90720.

157 Ricketts, E. F., J. Calvin, and J. W. Hedgpeth. 1968. Between Pacific tides, 4th edition. Stanford Univ. Press, Stanford, CA, 614 p.

158 Sayce, C. S., and D. F. Tufts. 1972. The effect of high water temperature on the razor clam, Siligua patula (Dixon). Proc. Natl. Shellfish Assoc. 62:31-34.

159 Scarlato, O. A. 1955. Class Bivalvia (= Lamellibranchiata, Pelecypoda). In E. N. Pavlovskii (editor), Atlas bespozvonchnykh dal'nevostochnykh morei SSSR (Atlas of the invertebrates of the Far Eastern Seas of the USSR), p. 253-270. Akad. Nauk. SSSR. Zool Inst., Moskva. [In Russian] (Transl. by Isr. Prog. Sci. Trans., Jerusalem, 1966. Available from CFSTI, Springfield, VA. TT66-51067.).

160 Schink, T. D., K. A. McGraw, and K. K. Chew. 1983. Pacific Coast clam fisheries. Wash. Sea Grant Prog., Univ. Wash., Seattle, 72 p.

161 Schultze, D. L., California Department of Fish and Game, 1416 Ninth Street, Sacramento, CA 95814. Pers. commun., March 1988.

162 Schultze, D. L. 1984. Digest of California commercial fish laws, January 1, 1984. Calif. Dep. Fish and Game, Sacramento, CA 95814.

163 Seapy, R. R., and C. L. Kitting. 1978. Spatial structure of an intertidal molluscan assemblage on a sheltered sandy beach. Mar. Biol. 46:137-145.

164 Shaul, W., and L. Goodwin. 1982. Geoduck (Panope generosa: Bivalvia) age as determined by internal growth lines in the shell. Can. J. Fish. Aquat. Sci. 39(4):632-636.

165 Simons, D., Washington Dep. of Fisheries, Shellfish Program, Montesano, WA. Pers. commun., June 1987.

166 Sloan, N. A., and S. M. C. Robinson. 1983. Winter feeding by asteroids on a subtidal sandbed in British Columbia. Ophilia 22(2):125-140.

167 Sloan, N. A., and S. M. C. Robinson. 1984. Age and gonad development in the geoduck clam Panope abrupta (Conrad) from southern British Columbia, Canada. J. Shellfish Res. 4(2):131-137.

168 Smith R. I., and J. T. Carlton. 1975. Light's manual: Intertidal invertebrates of the central California coast, 3rd edition. Univ. Calif. Press, Berkeley, CA, 716 p.

169 Span, J. A. 1978. Successful reproduction of giant Pacific oysters in Humboldt Bay and Tomales Bay, California. Calif. Fish Game 64(2):123-124.

170 Sparks, A. K., and K. K. Chew. 1966. Gross infestation of the littleneck clam, Venerupis staminea, with a larval cestode (Echeneibothrium sp.). J. Invert. Pathol. 8:413-416.

171 Staeger, W. H., and W. F. Horton. 1976. Fertilization method quantifying gamete concentrations and maximizing larvae production in Crassostrea gigas. Fish. Bull.,U.S. 74(3):698-701.

172 Starr, R. M., and J. E. McCrae. 1982. Scallop resource assessment. Annual Report, 70 p. Oreg. Dep. Fish. Wildl., Marine Science Drive, Bldg. 3, Newport, OR 97365.

173 Starr, R., Oregon Department of Fish and Wildlife, Newport, OR. Pers. commun., June 1987.

174 Sunada, J., California Department of Fish and Game, 245 W. Broadway, Long Beach, CA. Pers. commun., February 1987.

175 Talent, L. G. 1976. Food habits of the leopard shark, Triakis semifasciata, in Elkhorn Slough, Monterey Bay, California. Calif. Fish Game 62(4):286-298.

176 Tegleberg, H. C., and C. D. Magoon. 1969. Growth, survival, and some effects of a dense razor clam set in Washington. Proc. Natl. Shellfish. Assoc. 59:126-135.

177 Tegleberg H., D. Magoon, and M. Leboki. 1971. The 1969 and 1970 razor clam fisheries and sampling program. Wash. Dep. Fish. Prog. Rep., March 1971, 109 p.

178 Tegner, M. J., and R. A. Butler. 1985. Survival and mortality of seeded and native red abalones, Haliotis rufescens, on the Palos Verdes Peninsula. Calif. Fish Game 71(3):150-163.

179 Turner, C. H., and J. C. Sexsmith. 1967. Marine baits of California. 1st revision. Callf. Dep. Fish and Game, Sacramento, CA 98504, 70 p.

180 Washington State Department of Fisheries. 1960. Washington state shellfish. Wash. Dep. Fish., Olympia, WA 98504, 12 p.

181 Washington State Department of Fisheries. 1984. 1984-85 salmon, shellfish, marine fish sport fishing guide. Wash. Dep. Fish., Olympia, WA 98504, 24 p.

182 Washington State Department of Fisheries. 1984. 1982 Fisheries Statistical report. Compiled and edited by W. D. Ward and L. J. Hoines. Wash. Dep. Fish., Olympia, WA 98504, 77 p.

183 Washington State Department of Fisheries. 1984. 1983 fisheries statistical report. 99 p. Wash. Dep. Fish., Olympia, WA 98504.

184 Washington State Department of Fisheries. 1985. 1985-86 salmon, shellfish, bottomfish sport fishing guide. 20 p. Wash. Dep. Fish., Olympia, WA 98504.

185 Washington State Department of Fisheries. 1985. 1981-1983 shellfish and salmon commercial catches by species and statistical subarea for the state of Washington. Computer printout provided by Dale Ward, Computer Services Section, Wash. Dep. Fish., Olympia, WA 98504, 71 p.

186 Washington State Department of Fisheries. 1985. 1984 fisheries statistical report. 101 p. Compiled and edited by W. D. Ward and L. J. Hoines. Wash. Dep. Fish., Olympia, WA 98504.

187 Wendell, F., J. D. DeMartini, P. Dinnel, and J. Siecke. 1976. The ecology of the gaper or horse clam, Tresus capax (Gould) (Bivalvia:Mactridae), in Humboldt Bay, California. Calif. Dep. Fish Game Fish Bull. 62(1):41-64.

188 Weymouth, F. W., H. C. McMillin, and H. B. Holmes. 1925. Growth and age at maturity of the Pacific razor clam, Siligua patula (Dixon). U.S. Dep. Commer., Bur. Fish. Doc. 984:201-236.

189 Whyte, J. N. C., and J. R. Englar. 1982. Seasonal variation in chemical composition and condition indices of the Pacific oyster, Crassostrea gigas, grown in trays or on the sea bed. Can. J. Fish. Aquat. Sci., 39:1084-1094.

190 Wolotira, R. J., Jr., T. M. Sample, S. F. Noel, R. L. Henry, and C. R. Iten. In prep. Distribution maps for several species of commercially important fishes and shellfishes off the coast of North America, and associated depth distribution tables. Available from Natl. Mar. Fish. Serv., Northwest and Alaska Fish. Cent., 7600 Sand Point Way NE, Seattle, WA 98115.

191 Yonge, C. M. 1966. Oysters, 2nd edition. Collins, London, 209 p.

192 Zyblut, E. R., Canada Department of Fisheries and Oceans, Vancouver, B.C. Pers. commun., February 1985.

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APPENDIX A. --COMMON AND SCIENTIFIC NAMES FOR INVERTEBRATES AND FISHES MENTIONED IN THE SPECIES SYNOPSES.

Common name	Scientific name
INVERTEBRATES	
boring sponges	Cliona spp.
sea pen	Ptilosarcus gurneyi
purple alpheid shrimp	Bataeus harfordi
burrowing "ghost shrimp"	Upogebia sp.
	Callianassa spp.
shore crabs	Hemigrapsus spp.
sheep crab	Loxorhynchus grandis
Pacific rock crab	Cancer antennarius
yellow crab	Cancer anthonyi
slender crab	Cancer gracilis
red crab	p r o d u c t u s
pebble crab	CYcloxanthops novemdentatus
pea crabs	Pinnixa faba
	P. littoralis
commensal mussel crabs	Fabia concharum
	F. subguadrata
black turbans	Tegula funebralis
obtuse fossarus snail	Iselica obtusa
northern moon snail	Polinices lewisi
southern moon snail	P. reclusianus
oyster drill	Ocenebra japonica
Kellet's whelk	Kelletia killeti
pyramidellid snails	Odostomia spp.
date mussel	Lithophaga plumula
ribbed horse mussel	Arcuatula demissa
bay or blue mussel	Mytilis edulis
horse mussels	Modiolus spp.
baltic macoma	Macoma balthica
yellow metis	Leporimetis obesa
northern quahog	Mercenaria mercenaria
smooth Pacific venus clam	Chione fluctifraga
frilled California venus clam or wavy chione cockle	Chione undatella
thin-shelled littleneck	Protothaca tenerrima
butter clam	Saxidomus ginanteus
softshelled clam	Mya arenaria
false mya	Cryptomya californica
piddocks or pholadid clams	Penitella spp.

APPENDIX A. --Continued.

Common name	Scientific name
two-spotted octopus	Octopus bimaculoides
red sea urchin	Strongylocentrotus franciscanus
purple sea urchin	Strongylocentrotus purpuratus
leather star	Dermasterias imbricata
mottled star	Evasterias troschelii
pink seastar	Pisaster brevispinus
ochre seastar	Pisaster ochraceus
sunflower star or sunstar	Pycnopodia helianthoides
sea cucumber	Parastichopus californicus
PLANTS	
eelgrass	Zostera marina
green algae	
sea lettuce	Ulva spp.
brown algae	
bull kelp	Nereocystis sp.
palm kelp	Postelsia palmaeformis
laminaria kelp	Laminaria spp.
feather-boa kelp	Egregia sp.
sea-oaks	Eisenia sp.
giant kelp	Macrocystis spp.
elk kelp	Pelagophycus porra
red algae	Rhodophyta
coralline algae	Lithothamnium spp.
FISHES	
leopard shark	Triakis semifasciata
spiny dogfish	Squalus acanthias
bat ray	Myliobatis californicus
California moray	Gymnothorax mordax
Pacific herring	Clupea pallasi
California corbina	Menticirrhus undulatus
California sheephead	Pimelometopon pulcher
bay goby	Lepidogobius lepidus
lingcod	Ophiodon elongatus
cabezon	Scorpaenichthys marmoratus
starry flounder	Platichthys stellatus

APPENDIX B. --PLACE NAMES GAZETTEER FOR SPECIES SYNOPSES.

Place	Nation	State or Province	Latitude	Longitude
Adak Island	USA	Alaska	5200.00N	17645.00W
Adak Strait	USA	Alaska	5147.00N	17700.00w
Admiralty Inlet	USA	Washington	4806.00N	12241.00W
Afognak Island	USA	Alaska	5815.00N	15230.00W
Agate Pass	USA	Washington	4743.00N	12233.50W
Agattu Island	USA	Alaska	5220.00N	17325.00W
Aialik Bay	USA	Alaska	5940.000N	14934.00w
Alaska Peninsula	USA	Alaska	5615.00N	15920.00w
Albatross Bank	USA	Alaska	5630.00N	15230.00W
Aleutian Islands	USA	Alaska	5150.00N	17700.00w
Alitak Bay	USA	Alaska	5653.00N	15110.00w
Alitak Flats	USA	Alaska	5646.00N	15450.00w
Alsea River (and Bay)	USA	Oregon	4425.00N	12403.00W
Aleutian Basin	USA	Alaska	5500.00N	16300.00W
Aleutian Trench	USA	Alaska	5027.00N	17610.00E
Amchitka Island	USA	Alaska	5111.00N	17855.00E
Amukta Pass	USA	Alaska	5230.00N	17200.00W
Anacapa Island	USA	California	3400.00N	11920.00w
Arguello Canyon	USA	California	3422.00N	12100.00w
Ascunsion Island (Also Isla Ascunsion)	Mexico	Baja Calif. Sur	2706.50N	11417.50w
Astoria Bay	USA	Oregon	4613.00N	12345.00W
Astoria Canyon	USA	Oregon	4611.00N	12438.00W
Attu Island	USA	Alaska	5304.00N	17250.00E
Augustine Island	USA	Alaska	5918.00N	15326.00W
Bahia Asuncion (Also Ascunsion Bay)	Mexico	Baja Calif. Sur	2810.00N	11420.00W
Bahia Ballenas (Also Ballenas Bay)	Mexico	Baja Calif. Sur	2645.00N	11327.00W
Bahia Concepcion (Also Concepcion Bay)	Mexico	Sonora	2655.00N	11150.00w
BAJA California Norte	Mexico	---	2925.00N	11430.00w
Baja California Sur	Mexico	---	2630.00N	11220.00w
Baranof Island	USA	Alaska	5645.00N	13510.00w
Barkley Sound	Canada	British Columbia	4850.00N	12516.00W
Bear Seamount	---	---	4603.00N	13012.00W
Bechevin Bay	USA	Alaska	5500.00N	16323.00W
Bellingham Bay	USA	Washington	4900.00N	12249.00w
Bering Sea	---	---	5800.00N	16600.00w
Bering Strait	USSR/USA	---	6555.00N	16850.00W
Bodega Bay	USA	California	3821.00N	12303.20W
Bodega Head	USA	California	3818.00N	12313.20W

APPENDIX B. --Continued.

Place	Nation	State or Province	Latitude	Longitude
Bolinas Lagoon	USA	California	3802.00N	12255.00W
Bowie Canyon	---	---	5237.00N	17910.00E
Bowie Seamounts	---	---	5320.00N	13540.00w
Bowers Bank	USA	Alaska	5415.00N	17930.00E
Bowers Basin	USA	Alaska	5315.00N	17700.00E
Bowers Canyon	USA	Alaska	5310.00N	17910.00w
Bowers Ridge	USA	Alaska	5435.00N	17800.00E
Bristol Bay	USA	Alaska	5752.00N	15905.00w
British Columbia	Canada	---	5355.00N	12259.00w
Brookings	USA	Oregon	4204.00N	12417.00W
Budd Inlet	USA	Washington	4659.00N	12255.00W
Burrad Inlet	Canada	British Columbia	4915.00N	12306.00W
California	USA	---	3717.00N	12029.00w
Canal De Ballenas	Mexico	Baja Calif. Norte	2900.00N	11321.00W
Cape Alava	USA	Washington	4810.00N	12444.00W
Cape Blanco	USA	Oregon	4250.20N	12433.80W
Cape Chacon	USA	Alaska	5438.00N	13200.00W
Cape Douglas	USA	Alaska	5853.00N	15318.00W
Cape Elizabeth	USA	Washington	4722.00N	12418.00W
Cape Fairweather	USA	Alaska	5849.00N	13759.00w
Cape Flattery	USA	Washington	4823.50N	12441.10W
Cape Gamova	USSR	---	4232.00N	13112.00E
Cape Igvak	USA	Alaska	5727.00N	15600.00W
Cape Johnson	USA	Washington	4758.00N	12440.00W
Cape Kasilof	USA	Alaska	6022.00N	15122.00W
Cape Mendocino	USA	California	4026.40N	12424.30W
Cape Mordvinof	USA	Alaska	5455.00N	16439.00W
Cape Muzon	USA	Alaska	5433.00N	13240.00W
Cape Navarin	USSR	---	6216.00N	17910.00E
Cape Nukshak	USA	Alaska	5823.30N	15358.45W
Cape Nushagak	USA	Alaska	5843.00N	15829.00W
Cape Ommaney	USA	Alaska	5610.00N	13440.00w
Cape Perpetua	USA	Oregon	4415.50N	12406.50W
Cape San Lucas (Also Cabo San Lucas)	Mexico	Baja Calif. Sur	2245.00N	10959.00w
Cape Seniavin	USA	Alaska	5624.00N	16012.00W
Cape Shoalwater	USA	Washington	4644.00N	12406.00W
Cape Spencer	USA	Alaska	5814.00N	13640.00W
Cape Suckling	USA	Alaska	6000.00N	14350.00w
Carmel	USA	California	3633.00N	12155.00W

APPENDIX B. --Continued.

Place	Nation	State or Province	Latitude	Longitude
Carr Inlet	USA	Washington	4715.00N	12240.00W
Cascadia Seamount	---	---	4640.00N	12720.00W
Case Inlet	USA	Washington	4718.00N	12243.00W
Cayucos	USA	California	3528.00N	12054.00W
Cedros Island (Also Isla Cedros)	Mexico	Baja Calif. Norte	2825.00N	11510.00w
Channel Islands	USA	California	3342.00N	12000.00w
Chatham Sound	Canada	British Columbia	5418.00N	13017.00w
Chatham Strait	USA	Alaska	5703.00N	13432.00W
Chichagof Island	USA	Alaska	5730.00N	13530.00w
Chignik Bay	USA	Alaska	5622.00N	15820.00W
Chiniak Bank	USA	Alaska	5739.00N	15210.00W
Chirikof Island	USA	Alaska	5545.00N	15540.00w
Chilkoot Inlet	USA	Alaska	5900.00N	13513.00w
Chukchi Sea		---	6800.00N	17000.00w
Clatsop Beach	USA	Washington	4610.00N	12357.00W
Clayoquot Sound	Canada	British Columbia	4915.00N	12600.00W
Cobb Seamount	---	---	4645.00N	13050.00w
College Fjord	USA	Alaska	6100.00N	14801.00W
Columbia River	USA	Alaska	4618.00N	12330.00W
Commander Islands (Also Kommandorsky Islands)	USSR	---	5500.00N	16700.00E
Cook Inlet	USA	Alaska	5905.00N	15230.00W
Coos Bay	USA	Oregon	4323.00N	12421.00W
Copalis BEACH	USA	Washington	4707.00N	12411.00W
Copper River	USA	Alaska	6042.00N	14430.00w
Cordel Bank	USA	---	3801.00N	12326.00W
Cordova Bay	USA	Alaska	6036.00N	14636.00W
Coronation Gulf	USA	Alaska	6800.00N	11200.00w
Cortez Bank	USA	---	3225.00N	11915.00w
Crescent CITY	USA	California	4144.20N	.12411.40W
Dall Island	USA	Alaska	5500.00N	13329.00w
Dana Passage	USA	Washington	4714.00N	12250.00W
Dana Point	USA	California	3320.75N	11743.00w
Davidson Bank	USA	---	5355.00N	16410.00W
Davidson Inlet	USA	Alaska	5603.00N	13329.00w
Davidson Seamount	---		3545.00N	12242.00W
Delgada Canyon	USA		4004.00N	12409.00w
Dellwood Seamounts	---		5030.00N	13030.00w
Destruction Island	USA	Washington	4740.50N	12429.00w
Dixon Entrance	USA/CAN	---	5427.00N	13300.00w
Douglas Channel	Canada	British Columbia	5327.00N	12918.00W

APPENDIX B. --Continued.

Place	Nation	State or Province	Latitude	Longitude
Dungeness Spit	USA	Washington	4812.00N	12311.00W
El Canyon	USA	---	4037.00w	12431.00W
Eickenberg Ridge	---	---	4835.00N	13320.00W
Eickenberg Seamount	---	---	4830.00N	13307.00w
Elkhorn Slough	USA	California	3655.00N	12154.00W
English Bay	Canada	British Columbia	4917.00N	12310.00W
Ensenada	Mexico	Baja Calif. Norte	3152.00N	11637.00W
Ernest Sound	USA	Alaska	5611.00N	13218.00W
Explorer Seamount	---	---	4903.00N	13056.00W
Fairweather Grounds	USA	Alaska	5820.00N	13850.00W
Farallon Islands	USA	California	3740.00N	12300.00W
Fitzhugh Sound	Canada	British Columbia	5137.00N	12756.00W
Fraser River	Canada	British Columbia	4910.00N	12320.00W
Frederick Sound	USA	Alaska	5650.00N	13425.00W
Freshwater Bay	USA	Alaska	5751.00N	13459.00w
Gilbert Seamount	---	---	5230.00N	15000.00w
Glacier Bay	USA	Alaska	5840.00N	13627.00W
Gorda Valley	USA	California	3952.00N	12503.00W
Graham Island	Canada	British Columbia	5352.00N	13232.00W
Grayland	USA	Washington	4648.00N	12405.00W
Grays Harbor	USA	Washington	4653.30N	12406.90W
Guadalupe Island (Also Isla Guadalupe)	Mexico	Baja Calif. Norte	2845.00N	11820.00W
Gulf Islands	Canada	British Columbia	4910.00N	12355.00W
Gulf Of Alaska	---	---	5600.00N	14500.00w
Gulf Of Anadyr	USSR	---	6430.00N	17830.00W
Gulf Of California	Mexico	---	2640.00N	11050.00w
Guide Seamount	---	---	3704.00N	12320.00W
Gumdrop Seamount	---	---	3731.00N	12328.00W
Halfmoon Bay	USA	California	3731.00N	12231.00W
Hallo Bay	USA	Alaska	5827,00N	15357.00w
Hawaii	USA	---	1930.00N	15530.00w
Hawley Ridge	---	---	5100.00N	1763.00W
Hecata Bank	USA	Oregon	4406.00N	12452.00W
Hecate Strait	Canada	British Columbia	5300.00N	13100.00w
Heck Seamount	---	---	4820.00N	12950.00w
Herendeen Bay	USA	Alaska	5543.00N	16050.00W
Hinchinbrook Entrance	USA	Alaska	6020.00N	14650.00W
Hokkaido Island	Japan	---	4300.00N	14300.00E
Homer (Homer Spit)	USA	Alaska	5938.00N	15133.00w
Honshu	Japan	---	3603.00N	13800.00E
Hood Canal	USA	Washington	4730.00N	12230.00W
Howe Sound	Canada	British Columbia	4936.00N	12317.00W

APPENDIX B. --Continued.

Place	Nation	State or Province	Latitude	Longitude
Hueneme	USA	California	3409.00N	11912.50w
Humboldt County	USA	California	4050.00N	12350.00W
Humboldt Bay	USA	California	4045.90N	12413.70W
Huntington Beach	USA	California	3340.00N	11800.00W
Icy Strait	USA	Alaska	5820.00N	13545.00w
Isla Angel De La Guarda	Mexico	Baja Calif. Sur	2916.00N	11322.00W
Isla Maria Madre	Mexico	Nayarit	2135.00N	10615.00W
Isla Natividad	Mexico	Baja Calif. Sur	2750.00N	11510.00w
Isla Tiburon	Mexico	Baja Calif. Sur	2900.00N	11221.00w
Izembeck Lagoon (Bay)	USA	Alaska	5520.00N	16248.00W
Jalisco			2022.00N	10350.00w
Johnstone Strait	Canada	British Columbia	5022.00N	12559.00w
Juan De Fuca Canyon	USA/Can.	---	4800.00N	12520.00W
Juneau	USA'	Alaska	5820.00N	13420.00W
Kachemak Bay	USA	Alaska	5932.00N	15152.00W
Kalaloch	USA	Washington	4736.30N	12422.70W
Kalekta Bay	USA	Alaska	5359.00N	16620.00W
Kamchatka Peninsula	USSR	---	5700.00N	16000.00E
Kanak Island	USA	Alaska	6008.00N	14421.00W
Kenai Peninsula	USA	Alaska	6008.00N	15010.00w
Ketchikan	USA	Alaska	5520.30N	13138.45W
Kilisut Harbor	USA	Washington	4803.00N	12242.50W
Kingcome Inlet	Canada	British Columbia	5046.00N	12623.00W
Kiska Island	USA	Alaska	5150.00N	17723.00E
Knight Inlet	Canada	British Columbia	5038.00N	12634.00W
Knight Island Passage	USA	Alaska	6020.00N	14800.00W
Kobuk River	USA	Alaska	6655.00N	15910.00w
Kodiak	USA	Alaska	5750.00N	15210.00W
Kodiak Island	USA	Alaska	5728.00N	15334.00w
Kodiak Seamounts	---	---	5500.00N	13930.00w
Kommandorskiye Basin	---	---	5720.00N	16700.00E
Koryak Coast	USSR	---	6120.00N	17335.00E
Kotzebue Sound	USA	Alaska	6627.00N	16300.00W
Kruzof Island	USA	Alaska	5710.00N	13540.00w
Kyuquot Sound	Canada	British Columbia	4948.00N	12717.00W
Kvichak	USA	Alaska	5858.00N	15656.00W
Kyushio	Japan	---	3242.00N	13111.00E
Kyushu Island	Japan	---	3242.00N	13111.00E
La Jolla	USA	California	3250.00N	11717.00w
La Jolla Canyon	USA	California	3258.00N	11732.00W
La Paz	Mexico	Baja Calif. Sur	2405.00N	10939.00w
La Perouse Bank	---	---	4835.00N	12548.00W
Little Diomede Island	USA	Alaska	6545.00N	16855.00W

APPENDIX B. --Continued.

Place	Nation	State or Province	Latitude	Longitude
Lituya Bay	USA	Alaska	5836.45N	13739.30w
Long Beach	USA	California	3346.00N	11810.00W
Long Beach	Canada	British Columbia	4900.00N	12539.00w
Los Angeles Harbor	USA	Alaska	3333.00N	11816.00w
Los Coronados Islands	Mexico	Baja Calif. Norte	3229.00N	11718.00W
Lynn Canal	USA	Alaska	5850.00N	13515.00w
Magdalena Bay (Also Bahia Magdalena)	Mexico	Baja Calif. Sur	2440.00N	11200.00w
Makushin Bay	USA	Alaska	5340.00N	16700.00W
Malibu Point	USA	California	3402.00N	11841.00W
Malispina Strait	Canada	British Columbia	4930.00N	12404.00W
Manhattan Beach	USA	California	3344.00N	11824.00W
Manzanillo	Mexico	Colima	1900.00N	10420.00W
Marina Del Rey	USA	California	3350.00N	11825.00W
Mattole Canyon	---	---	4018.00N	12424.00W
Mazatlan	Mexico	Sin	2313.00N	10625.00W
Mendocino Canyon	---	---	4028.00N	12427.00W
Mendocino County	USA	California	3930.00N	12330.00W
Mendocino Ridge	---	---	4024.00N	12734.00W
Middle Canyon	---	---	5830.00N	17605.00W
Milbanke Sound	Canada	British Columbia	5215.00N	12854.00W
Mission Bay	USA	California	3247.00N	11713.00w
Mocrocks Beach	USA	Washington	4714.50N	12413.00W
Montague Island	USA	Alaska	5942.00N	14720.00W
Monterey (Bay)	USA	Alaska	3635.00N	12156.00W
Monterey Canyon	---	---	3638.00N	12217.00W
Morro Bay	USA	California	3521.80N	12052.10W
Morzhovoi Bay	USA	Alaska	5500.00N	16300.00W
Navarin Ridge	---	---	5840.00N	17645.00W
Navarin Canyon	---	---	6010.00N	17810.00W
Navarro Canyon	---	---	3906.00N	12406.00W
Nayarit (State)	Mexico	---	2200.00N	10500.00w
Netarts Bay	USA	Oregon	4524.00N	12357.00W
Newport	USA	Oregon	4439.00N	12404.00W
Newport Bay	USA	California	3333.00N	11745.00w
Nome	USA	Alaska	6433.00N	16500.00W
Nootka Sound	Canada	British Columbia	4942.00N	12650.00W
Norton Sound	USA	Alaska	6400.00N	16400.00W
Noyo Canyon	---	---	3930.00N	12425.00W
Nuka Bay	USA	Alaska	5919.00N	15033.00w
Nunivak Island	USA	Alaska	6007.00N	16600.00w
Observatory Inlet	Canada	British Columbia	5510.80N	12940.75w
Ocean Bay	USA	Alaska	5705.00N	15310.00w

APPENDIX B. --Continued.

Place	Nation	State or Province	Latitude	Longitude
Ocean Shores	USA	Washington	4700.00N	12410.00W
Olga Bay	USA	Alaska	5705.00N	15425.00W
Olympia	USA	Washington	4703.00N	12254.00W
Olyutorskii Bay	USSR	---	6000.00N	16800.00E
Oregon	USA	---	4400.00N	12100.00w
Oyster Bay	Canada	British Columbia	4955.000	12511.00W
Pathfinder Seamount	---	---	5055.00N	14320.00W
Palos Verdes Peninsula	USA	California	3347.00N	11817.00W
Pacific Beach	USA	Washington	3248.00N	11715.50w
Parks Seamount	USA	California	4413.00N	12955.00w
Patton Seamount	---	---	5430.00N	14900.00w
Pavlof Bay	USA	Alaska	5530.00N	16130.00W
Pendrell Sound	Canada	British Columbia	5015.00N	12444.00W
Petersburg	USA	Alaska	5648.00N	13258.00W
Petrel Bank	---	---	5208.00N	17948.00W
Pervenets Canyon	---	---	5925.00N	17800.00W
Pervenets Ridge	---	---	6000.00N	17740.00w
Pioneer Canyon	---	---	3725.00N	12314.00W
Pioneer Seamount	---	---	3718.00N	12320.00W
Pismo Beach	USA	California	3510.00N	12037.00W
Point Arena	USA	California	3857.00N	12343.00W
Point Arguello	USA	California	3435.00N	12039.00w
Point Baja (Also Punta Baja)	Mexico	Baja Calif. Norte	3000.00N	11550.00w
Point Barrow	USA	Alaska	7132.00N	15630.00W
Point Buchon	USA	California	3515.00N	12045.00W
Point Conception	USA	California	3423.90N	12028.20W
Point Descanso (Also Punta Descanso)	Mexico	Baja Calif. Norte	3200.00N	11650.00W
Point Dume	USA	California	3400.00N	11848.00W
Point Hope	USA	Alaska	6820.00N	16750.00W
Point Lobos	USA	California	3746.50N	12235.00W
Point Loma	USA	California	3240.00N	11714.50w
Point Montara	USA	California	3732.00N	12231.00W
Point Mugu	USA	California	3410.00N	11913.00w
Point Pinos	USA	California	3638.00N	12156.00W
Point Reyes	USA	California	3759.00N	12259.00w
Point San Juanico (Also Punta San Juanico)	Mexico	Baja Calif. Sur	2603.00N	11218.00W
Polly Creek	USA	Alaska	6017.00N	15227.00W
Port Frederick	USA	Alaska	5813.00N	13530.00w
Port Moller	USA	Alaska	5559.30N	16034.30W
Port Orchard	USA	Washington	4700.00N	12236.00W

APPENDIX B. --Continued.

Place	Nation	State or Province	Latitude	Longitude
Port Susan	USA	Washington	4810.00N	12220.50W
Port Townsend	USA	Washington	4809.00N	12248.00W
Port Wells	USA	Alaska	6048.00N	14814.00W
Portlock Bank	USA	---	5823.00N	15005.00w
Possession Sound	USA	Washington	4800.00N	12220.00w
Powell River	Canada	British Columbia	4954.00N	12434.00W
President Jackson Seamount	---	---	4232.00N	12747.00W
Pribilof Canyon	USA	---	5610.00N	16904.00W
Pribilof Islands	USA	Alaska	5700.00N	17000.00w
Prince Of Wales Island	USA	Alaska	5551.00N	13258.00W
Prince Rupert	Canada	British Columbia	5411.00N	13015.00w
Prince William Sound	USA"	Alaska	6045.00N	14655.00W
Puget Sound	USA	Washington	4750.00N	12230.00W
Punta Blanca	Mexico	Baja Calif. Norte	2926.00N	11448.00W
Punta Eugenia	Mexico	Baja Calif. Sur	2753.30N	11505.00w
Qualicum Beach	Canada	British Columbia	4940.00N	12425.00W
Queen Charlotte Island	Canada	British Columbia	5300.00N	13430.00w
Queen Charlotte Sound	Canada	British Columbia	5120.00N	12900.00w
Queen Charlotte Strait	Canada	British Columbia	5038.00N	12700.00W
Quinault Indian Reservation	---	---	4730.00N	12400.00W
Rivers Inlet	Canada	British Columbia	5125.00N	12750.00W
Rescue Bay	Canada	British Columbia	5231.00N	12817.00W
Resurrection Bay	USA	Alaska	5948.00N	14930.00W
Rodriguez Seamount	---	---	3402.00N	,12104.00W
Rosarito	Mexico	Baja Calif. Norte	3215.00N	11655.00W
Rude Canyon	---	---	5315.00N	17900.00E
Russell Fjord	USA	Alaska	6000.00N	13927.00w
Ryukyu Island	Japan	---	2620.00N	12830.00E
San Clemente Island	USA	California	3243.00N	11830.00W
San Cristobol Bay (Also Bahia San Cristobol)	Mexico	Baja Calif. Sur	2716.00N	11435.00w
San Diego	USA	California	3239.90N	11715.50w
San Francisco	USA	California	3755.00N	12300.20W
San Francisco Bay	USA	California	3749.00N	12182.00W
San Hipolito Bay (Also Bahia San Hipolito)	Mexico	Baja Calif. Sur	2659.00N	11356.00W
San Juan Islands	USA	Washington	4838.00N	12309.10W
San Juan Seamount	---	---	3303.00N	12100.00w
San Juanico	Mexico	Baja Calif. Sur	2602.00N	11219.00w
San Luis Obispo Bay	USA	California	3509.60N	12045.60W
San Mateo Point	USA	California	3733.00N	12222.00w
San Miguel Island	USA	California	3405.00N	12022.00w
San Nicolas Basin	USA	---	3254.00N	11900.00w

APPENDIX B . --Continued.

Place	Nation	State or Province	Latitude	Longitude
San Nicolas Island	USA	California	3310.00N	11930.00w
San Pablo Bay	USA	California	3756.00N	12230.00W
San Pedro	USA	California	3345.00N	11819.00W
San Pedro Bay	USA	California	3340.00N	11810.00W
San Quintin Bay (Also Bahia San Quintin)	Mexico	Baja Calif. Norte	3030.00N	11603.00W
San Simeon	USA	California	3539.00N	12111.00w
Sanak Bank	USA	Alaska	5417.00N	16200.00W
Sanak Island	USA	Alaska	5431.00N	16240.00W
Santa Barbara	USA	California	3420.80N	11943.30w
Santa Barbara Channel	USA	California	3415.00N	12000.00w
Santa Catalina Island	USA	California	3315.00N	11825.00W
Santa Cruz Basin	USA	---	3343.00N	11933.00w
Santa Lucia Bank	USA	---	3450.00N	12120.00w
Santa Lucia Escarpment	---	---	3142.00N	12146.00W
Santa Monica Basin	USA	---	3344.20N	11851.00W
Santa Monica Bay	USA	California	3355.00N	11834.00W
Santa Cruz County	USA	California	3659.00N	12156.00W
Santa Cruz Island	USA	California	3355.00N	11940.00w
Santa Rosilia Bay (Also Bahia Santa Rosilia)	Mexico	Baja Calif. Norte	2845.00N	11425.00W
Scammons Lagoon (Also Laguna Ojo De Libre)	Mexico	Baja Calif. Sur	2750.00N	11416.00W
Sea Of Japan	USSR/Japan	---	3900.00N	11500.00E
Seal Beach	USA	California	3344.30N	11806.00w
Sea Of Okhotsk	USSR	---	5500.00N	14850.00E
Sebastion Vizcaino Bay (Also Bahia Sebastion Viscaino)	Mexico	---	2800.00N	11440.00w
Security Cove	USA	Alaska	5848.00N	16200.00W
Seguam Pass	USA	Alaska	5210.00N	17300.00w
Selwyn Inlet	Canada	British Columbia	5250.00N	13139.00w
Semidi Islands	USA	Alaska	5610.00N	15647.00W
Seward Peninsula	USA	Alaska	6530.00N	16400.00W
Shelikof Strait	USA	Alaska	5730.00N	15500.00w
Shirsov Ridge	---	---	5820.00N	17000.00E
Shumagin Islands	USA	Alaska	5455.00N	16020.00W
Sidney Inlet	Canada	British Columbia	4835.50N	12317.50W
Sitka	USA	Alaska	5712.00N	13522.00W
Sitka Sound	USA	Alaska	5700.00N	13530.00w
Sitkinak Island	USA	Alaska	5633.00N	15410.00w
Sixty Mile Bank	USA	---	3204.00N	11813.00W
Skagit Bay	USA	Washington	4825.00N	12230.00W

APPENDIX B. --Continued.

Place	Nation	State or Province	Latitude	Longitude
Slime Bank	USA	---	5503.00N	16400.00W
Socorro Island (Also Isla Socorro)	USA	Alaska	1840.00N	11100.00w
Southern California Bight	USA	California	3350.00N	12000.00w
Spanish Canyon	---	---	4004.00N	12416.00W
Springfield Seamount	---	---	4804.00N	13010.00w
St. George Island	USA	Alaska	5632.00N	16925.00W
St. Lawrence Island	USA	Alaska	6345.00N	17030.00w
St. Matthew Canyon	---	---	5825.00N	17705.00w
St. Matthew Island	USA	Alaska	6036.00N	17242.00W
Stalemate Bank	USA	---	5300.00N	17000.00E
Stephens PASSAGE	USA	Alaska	5740.00N	13355.00w
Stepovak Bay	USA	Alaska	5540.00N	15950.00w
Stikine River Flats	USA	Alaska	5631.00N	13224.00W
Stonewall Bank	---	---	4434.00N	12425.00W
Strait Of Georgia	Canada	British Columbia	4917.00N	12350.00W
Strait Of Juan De Fuca	USA/CAN	---	4818.00N	12400.00W
Stuart Channel	USA	Alaska	6332.30N	16233.00W
Siuslaw River	USA	Oregon	4400.00N	12405.00W
Sumner Strait	USA	Alaska	5608.00N	13355.00w
Sunset Bay	USA	Oregon	4320.00N	12422.75W
Sur Canyon	---	---	3605.00N	12207.00W
Surveyor Seamount	---	---	5600.00N	14310.00w
Sutwik Island	USA	Alaska	5637.00N	15712.00W
Swikshak Beach	USA	Alaska	5836.30N	15341.30w
Taholah	USA	Washington	4721.00N	12418.00W
Tananga Pass	USA	Alaska	5133.00N	17820.00W
Tanner Bank	---	---	3250.00N	11938.00W
Tillamook Bay	USA	Oregon	4530.00N	12355.00W
Tillamook Head	USA	Oregon	4557.00N	12400.00W
Todos Santos Bay (Also Bahia Todos Santos)	Mexico	Baja Calif. Norte	3150.00N	11645.00W
Tofino Inlet	Canada	British Columbia	4909.00N	12554.00W
Tomales Bay	USA	California	3810.00N	12255.00W
Thompson Seamount	---	---	4602.00N	12840.00W
Tortugas Bay (Also Bahia Tortugas)	Mexico	Baja Calif. Sur	2740.00N	11453.00w
Totten Inlet	USA	Washington	4708.00N	12300.00W
Trinidad Head	USA	California	4103.50N	12409.00w
Tsushima Island	Japan	---	3511.00N	13645.00E
Tufts Plain	---	---	4800.00N	14400.00w
Umpqua River (Bay)	USA	Oregon	4342.00N	12330.00W
Unalaska Island	USA	Alaska	5318.00N	16650.00W

APPENDIX B. --Continued.

Place	Nation	State or Province	Latitude	Longitude
Unimak Bight	USA	Alaska	5430.00N	16350.00W
Unimak Island	USA	Alaska	5445.00N	16500.00W
Unimak Pass	USA	Alaska	5420.00N	16450.00W
Vancouver	Canada	British Columbia	4905.00N	12258.00W
Vancouver Island	Canada	British Columbia	4930.00N	12530.00W
Vashon Island	USA	Washington	4723.30N	12222.40W
Victoria	Canada	British Columbia	4825.00N	12330.00W
Vizcaino Canyon	---	---	3941.00N	12430.00W
Washington	USA	---	4738.00N	12000.00w
Willapa Bay	USA	Washington	4637.00N	12404.60W
Winchester Bay	USA	Oregon	4341.00N	12411.00W
Wrangell	USA	Alaska	5628.00N	13210.00W
Yakutat Bay	USA	Alaska	5940.00N	14000.00w
Yankee Point	USA	California	3640.00N	12200.00w
Yaquina Bay	USA	Oregon	4445.00N	12405.00W
Yaquina Head	USA	Oregon	4440.60N	12404.70W
Zhemchug Canyon	---	---	5820.00N	17450.00w

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APPENDIX C. --GLOSSARY OF TERMS USED IN SPECIES SYNOPSES.

ABYSSAL ZONE-- Open ocean bottom at depths of 4,000 to 6,000 meters.

ABYSSOPELAGIC-- Refers to the water column below 4,000 meters, the abyssopelagic zone.

ADDUCTOR MUSCLE-- A muscle, especially in molluscs, that pulls a part of the body toward the medium axis of the body. In bivalve molluscs, this muscle is used specifically to close the shells and hold them together.

ALEVIN -- The larval stage of trout and salmon that carries the yolk-sac during the time the fish are living under gravel.

ALEUTIAN PROVINCE -- A zoogeographical designation for faunal distributions that, based on minimum temperature requirements, extends from Puget Sound, Washington, to the Bering Strait.

ALGAE-- A collective, or general name, applied to a number of primarily aquatic, photosynthetic groups (taxa) of plants and plant-like protists. They range in size from single cells to large, multicellular forms like the giant kelps. They are the food base for almost all marine animals. Important taxa are the dinoflagellates (div. Pyrrophyta), diatoms (div. Chrysophyta), green algae (div. Chlorophyta), brown algae (div. Phaeophyta), and red algae (div. Rhodophyta). Cyanobacteria are often called blue-green algae, although blue-green bacteria is preferable.

AMPHIPODA -- An order of laterally compressed crustaceans with thoracic gills, no carapace, and similar body segments. Most are under one cm in length, and many are important members of the zooplankton. Some are bottom dwellers, and a few are parasitic.

AMPHI-NORTH PACIFIC -- Referring to population distributions where a given species might occur on the east and west rims of the Pacific Ocean, but not on the northern rim.

ANADROMOUS-- Indicates a life cycle where breeding and early life is spent in fresh water, while the remainder is spent at sea.

ANESTROUS-- Refers to female mammals when in the nonreproductive phase of their cycles. They are usually unresponsive to males in this phase.

ANTHROPOGENIC-- Alluding to the effects of human activities.

ANTITROPICAL-- Refers to a distribution in both hemispheres, excluding the tropical region.

ARCTIC REGION-- The oceans above the zero degree Celsius (0°C) winter isotherm. Along the Pacific coast, this corresponds approximately to 60° North latitude in the Bering Sea.

AREAL-- Refers to a measure of area.

ASCIDIAN-- A tunicate having a generalized saclike, cellulose body, such as the sea squirt.

APPENDIX C. --Continued.

AUSTRAL-- Relating to the south, or a terrestrial biogeographical zone between the transitional and tropical zones. This zone includes most of the United States through central Mexico in North America.

BATHYAL-- Refers to the zone of ocean bottom at depths of 200 to 4,000 meters, primarily on the continental slope and beyond.

BATHYMETRIC-- Refers to depth measurement, or to migrations from waters of one depth range to waters of another depth range.

BATHYPELAGIC-- Relates to the zone of ocean water from about 1,000 to 4,000 meters in depth.

BENTHIC -- Indicates a relationship to the ocean bottom (benthic realm), or to sessile and crawling animals of the sea floor.

BENTHOPELAGIC-- Refers to organisms that live above the ocean floor, but which feed on the bottom.

BENTHOPELAGIVORE-- A carnivore that feeds on the sea bottom while living in the pelagic realm above it.

BIGHT-- An inward bend or bow in the coastline.

BIOMASS-- The total weight of living tissues (wet or dried) of an organism, or collection of organisms of a species or trophic level from a defined area or volume.

BIVALVIA-- The most important commercial class of molluscs, also referred to as Pelecypoda. The shell is made of two halves (valves) connected by a hinge ligament. They are filter feeders and mostly sedentary. The class includes clams, oysters, scallops, and mussels.

BOREAL REGION -- The oceans between the 13°C winter isotherm and the 0°C winter isotherm. In neritic waters of western North America, it extends from Point Conception, California, to the Aleutian Islands.

BRANCHIAL-- A structure or location associated with the gill.

BRYOZOA-- A minute, mosslike animal of the phylum Ectoprocta, forming branching colonies that reproduce by budding.

BYSSAL THREAD -- A tuft of filament, chemically similar to silk, serving to attach certain molluscs to a substrate.

CARNIVORE -- Any animal that feeds on other animals after killing them, or by eating them alive. See PARASITISM and PREDATION. Carnivore may refer specifically to members of the mammalian order Carnivora.

CERCARIA-- A free-swimming larval form of the class Trematoda.

CESTODE -- A class of parasitic, ribbonlike worms having no intestinal canal (e.g., the tapeworms).

APPENDIX C.--Continued.

CHEMOTAXIS -- A response movement by an animal either toward or away from a specific chemical stimulus.

CHORDATA -- A major phylum of animals including the subphyla Vertebrata, Cephalochordata, and Urochordata. All have three characteristics at some stage of the life cycle: pharyngeal gill slits, a notochord, and a dorsal, hollow nerve cord.

CILIA -- Hairlike processes of certain cells, capable of rhythmic beating that can produce locomotion or facilitate the movement of fluids within ducts.

CIRRI -- Flexible, threadlike tentacles or appendages of certain organisms.

CLINE -- A gradually varying distribution of a physical characteristic such as salinity or temperature along a gradient like depth or latitude. With populations, a similar distribution of a biological feature such as size or color.

COLONY -- Among invertebrates, a colony is a close association of individuals of a species which are often mutually dependent and in physical contact with other colony members. When used with vertebrates, a colony usually is a group brought together for breeding and rearing young.

COMMENSALISM -- A relationship between two species populations in which the population of one species is benefited or increased while the second population is unaffected.

COMMUNITY -- In ecology, a community is all of the various species populations in a defined area or habitat. Further restrictions are often made with modifiers such as the algal community, the invertebrate community, the benthic gastropod community, etc.

COMPETITION -- Interspecific competition involves populations of two or more species that use one or more limited resources such as food, attachment sites, protective cover, or dissolved ions. These interactions tend to have a depressing effect on the populations involved. Intraspecific competition is among members of a population for limited resources needed by the species for survival and reproduction. This form of competition includes resources involved in interspecific competition as well as resources like mates and territories, and is generally more intense because resource needs are essentially identical among conspecifics. See NICHE.

CONTINENTAL SHELF -- An underwater plain that is part of a continental land mass and up to 200 meters below the sea. The shelf extends from the coastline to distances of a few miles to several hundred miles.

CONTINENTAL SLOPE -- The steeply inclined ocean bottom that bridges a continental shelf and ocean basin.

APPENDIX C. --Continued.

COPEPODA -- A subclass of crustaceans with about 4,500 species, including several specialized parasitic orders. The free-living species are small (one to several mm) with cylindrical bodies, one median eye, and two long antennae. One order is planktonic (Calanoida), one is benthic (Harpacticoida), and one has both planktonic and benthic species (Cyclopoida). Some head appendages form a complex filter apparatus in most species; these feed primarily on algae. Thoracic appendages are used for swimming or crawling on the bottom. This may be the most abundant group of animals on earth, and they are a major link in marine food webs.

CREPUSCULAR -- Relates to animals whose peak activity is between sunset and nightfall.

CRUSTACEA -- A large class of over 26,000 species of mostly aquatic arthropods with five pair of head appendages, including laterally opposed jaw-like mandibles and-two pair of antennae. Most have well-developed compound eyes and variously modified two-branched body appendages. The body segments are often differentiated into a forward thorax and an abdomen. Some common members are crabs, shrimp, lobsters, copepods, amphipods, isopods, and barnacles.

CTENOPHORA -- A large phylum of mostly marine organisms with an oval, jellylike body bearing eight rows of comblike plates that aid in swimming; ctenophores.

DECOMPOSERS -- Bacteria and fungi that ultimately break down dead organisms of all types to simple molecules and ions.

DEMERSAL -- Concerns swimming animals that live near sea bottom, or eggs that are denser than water and sink after being laid.

DEPOSIT FEEDER -- An animal that ingests soft sediments containing small organisms and detritus, or that filters organisms and dead material from such substrates.

DESICCATE-- To dry completely.

DETRITIVORE-- An organism that eats small particles of partially decomposed organic material (detritus). See DECOMPOSER.

DIATOMS -- Single-celled protistan algae of the division Chrysophyta that have intricate siliceous shells composed of two halves, like a box and lid. They range in size from about 10 to 200 micrometers, and the cells sometimes remain attached after divisions to form simple chains or colonies. These phytoplankters are the most numerous and important group among the ocean producers that form the food base for marine animals.

DIEL -- Relates to an activity cycle based on daily periods of light and dark. Circadian and diurnal are also used in relation to cycles of about 24 hours.

APPENDIX C. --Continued.

DIMORPHISM-- A condition where a population has two distinct physical forms (morphs). In sexual dimorphism, secondary sexual characteristics are markedly different (e.g., size, color, and behavior).

DINOFLAGELLATE -- A planktonic, unicellular protozoan typically bearing two flagella. Botanists and protozoologists have long belabored the classification of these organisms, as their characteristics resemble those of the plant and animal kingdom.

DIRECT DEVELOPMENT -- See EMBRYONIC DEVELOPMENT.

DISPERSAL-- In a more restricted sense, the movement of young animals away from their point of origin to locations where they will live at maturity. Generally, the spreading out of individuals throughout suitable habitat within or outside the population range.

DISTRIBUTION-- (1) A species distribution is the pattern of its population or populations over its geographic range. See RANGE. (2) A population depth distribution is the proportion or number of all individuals, or those of various sizes or ages, at different depth levels. (3) A population age distribution is the proportion of individuals of each sex in various age classes. (4) Within a population, individuals may be distributed evenly, randomly, or in groups throughout suitable habitat.

DIURNAL-- Refers to daylight activities, or organisms most active during daylight. May also refer to 24-hour cycles. See DIEL.

ECHINODERMATA-- A phylum of marine animals possessing a water vascular system, a hard, spiny skeleton, and radial symmetry, and including the sea stars and sea urchins; echinoderms.

ECTOPARASITE-- A parasite that attacks the host animal or plant from the outside. Feeding periods and/or attachment time may be brief compared to internal (endo-) parasites.

EELGRASS-- Seed plants of the genus Zostera that are adapted to living underwater while rooted in shallow sediments along coasts.

EL NIÑO CURRENT -- An intermittent warm water current from the tropics that overrides the opposing cold current along the pacific coasts of North and South America (see gyre). This raises near-surface temperatures, depresses the thermocline, and often suppresses upwelling, resulting in drastic drops in primary productivity and consequent high mortality among marine animals. This is most pronounced on the coast of Peru. Effects are not as severe in North America, but northward shifts in distributions of species are common in El Niño years.

EMBRYONIC DEVELOPMENT -- The increase in cell number, body size, and complexity of organ systems as an individual develops from a fertilized egg until hatching or birth. In direct development, the individual is essentially a miniature of the adult at this time. It grows and gradually changes until maturity. In indirect development, the newly hatched differ greatly from the adult, and go through periodic, major changes (larval stages and metamorphosis).

APPENDIX C. --Continued.

EMIGRATION-- A permanent movement by some members of a population out of an area occupied by that population. See IMMIGRATION.

ENDEMIC -- Relates to a species or other taxonomic group that is native to a geographical region.

EPIBENTHIC -- On the sea bottom, as opposed to in the substrate.

EPIDERMAL-- Refers to the surface or outer layer of skin.

EPIFAUNA-- Animals living on the surface of the sea bottom.

EPIPELAGIC-- Refers to the upper sunlit zone of oceanic water where phytoplankton live and organic production takes place (approximately the top 150 meters). See EUPHOTIC.

EPIPHYTIC-- Relates to the growth habit of living on a plant (e.g., mosses growing on trees).

EPIPODAL-- A structure or location associated with the leg or foot; typically refers to arthropod anatomy.

ESCARPMENT-- A sharp incline intopography as in a cliff or along the continental slope.

ESTUARY-- A partially enclosed body of water with an open connection to the sea, and one or more inflowing streams. There is a mixture of sea and freshwater (oligohaline or brackish). Typically, there is an influx of nutrients from the land resulting in high productivity, but with widely fluctuating physical conditions.

EUHALINE-- Water with salt concentrations of 30-40 ppt.

EUPHOTIC-- Refers to the upper levels of a water body where light penetrates and phytoplankton (algae) carry out photosynthesis (produce sugars from carbon dioxide and water using light energy). See EPIPELAGIC.

EURYHALINE-- Indicates a broad tolerance to salt concentrations.

EXTANT-- A species or other group of related organisms that is still in existence, not extinct.

FAUNA-- All of the animal species in a specified region.

FECUNDITY-- The potential of an organism to produce offspring. See REPRODUCTIVE POTENTIAL.

FILTER FEEDER -- Any of many species from a number of phyla that have adaptations for filtering small animals, plants, and detritus from water or fine sediments. Organs used include: gills in clams and oysters, baleen in whales, and specialized appendages in crustaceans and marine worms.

APPENDIX C.--Continued.

FLAGELLATE-- Refers to cells that possess organelles of motility or microorganisms that possess one or more flagellum used for locomotion.

FLORA -- All of the species of plants in a specified region.

FOOD WEB (CHAIN) -- The feeding relationships within a community of several to many species populations in a given area or region during a particular time period. Two broad types are recognized: grazing webs involve producers like algae, herbivores like copepods, and various combinations of carnivores and omnivores; detritus webs include scavengers, detritivores, and decomposers that feed on the dead remains of organisms from the grazing webs, as well as on their own dead. See TROPHIC LEVEL.

FRESHWATER-- By definition, water that has a salt concentration of from 0.0 to 0.5 ppt.

FRY-- Very young fish. In trout and salmon, young that have just emerged from the gravel and alevin larval stage.

GAMETE -- A reproductive cell that is haploid and can unite with another gamete to form the cell (zygote) that develops into a new individual.

GASTROPODA-- This is the largest class of molluscs, most of whom are herbivores. Most have shells that are often spiraled, and they move on a flat, undulating foot. They scrape food with an organ analogous to a tongue (radula). The class includes terrestrial snails and slugs as well as aquatic relatives such as whelks, turbans, limpets, conchs, abalones, and nudibranchs.

GROUNDFISH-- Any species of fish that lives on or near the bottom, also called bottomfish.

GYRE -- An ocean current that follows a circular path around an ocean basin, clockwise in the Northern Hemisphere and the reverse in the southern. Two of these move along the coasts of North America, down on the west and up on the east.

HABITAT-- The particular type of place where an organism lives within a more extensive area or range. The habitat is characterized by its biological components and/or physical features (e.g., sandy bottom of the littoral zone, or on kelp blades within 10 m of the water surface).

HADAL ZONE -- The deepest bottoms of ocean trenches with depths of over 6,000 m.

HAPLOSPORIDIAN-- A unicellular protozoan occurring in vertebrate and invertebrate hosts, possibly bearing pseudopodia, but never flagella.

HERBIVORE-- Any type of organism that preys on living producers such as phytoplankton, large algae, or higher plants.

HERMAPHRODITIC-- Organisms having both male and female sex organs in the same individual.

APPENDIX C. --Continued.

HOLARCTIC -- The entire arctic realm including the Paleoarctic (Europe and Asia) and the Nearctic (North America). Also, the entire arctic region in oceanography.

HOOKA -- A modified scuba diving apparatus designed to receive air from the surface through a hose connected at the regulator.

HYDROZOA -- A class of coelenterate animals with a mostly nonmotile adult stage, characterized by a saclike body composed of two layers of cells and a mouth that opens directly into the body cavity; hydrozoan or hydroid.

HYPERSALINE-- Water with a salt concentration over 40 ppt.

HYPOLIMNION -- The zone of lake water below the thermocline.

IMMIGRATION-- A one-way movement of conspecifics into a population or breeding unit (deme or subpopulation). See EMIGRATION, MIGRATION, and RECRUITMENT.

INDIRECT DEVELOPMENT -- See EMBRYONIC DEVELOPMENT.

INFAUNA-- Animals living in the substrate of the sea bottom.

INNER SHELF -- The continental shelf nearest shore that extends from the mean low tide line to the 20 m isobath.

INSULAR-- Refers to characteristics of islands.

INTEROPAROUS-- Relates to organisms that have a number of reproductive periods during their lifespan.

INTERTIDAL-- The portion of the ocean floor exposed between highest and lowest tides.

ISOBATH-- A contour mapping line indicating a specified constant depth.

ISOPODA-- An order of about 4,000 species of dorsoventrally compressed crustaceans with abdominal gills and similar abdominal and thoracic segments. Terrestrial pillbugs and thousands of benthic, marine species are included. Most species are scavengers and/or omnivores, and a few are parasitic.

ISOTHERM-- A geographical contour line connecting points of equal mean temperature for a given time interval.

KINESIS-- A randomly directed movement by an animal in response to a sensory stimulus such as light, heat, or touch. When the response is directed, it is called a taxis. See CHEMOTAXIS.

LACUSTRINE-- Refers to something from or pertaining to lakes.

LAGOON-- A shallow pond or channel linked to the ocean.

APPENDIX C. --Continued.

LARVAE -- A developmental stage in the life cycle that is very different from the adult form in organisms with indirect development. See EMBRYONIC DEVELOPMENT.

LATERAL LINE -- A canal system with pressure sensors under the skin on both sides of the body of most fishes. The system connects indirectly with the inner ear and functions in sensing changes in water pressure due to movements in the water, including sound waves.

LITTORAL-- Refers to the area between the mean low and high tide levels. Water here is the littoral zone of the pelagic realm, and the bottom is the littoral zone of the benthic realm.

MANTLE -- The upper folded layer of skin in molluscs that extends over the sides enclosing the gills and most of the body in a cavity above the muscular foot. In squids and allies, the mantle is below the body and behind the tentacles (derived from the foot) due to the shift in the dorsal-ventral axis. The mantle produces the shell in species having them.

MEAN LOWER LOW WATER (MLLW) -- The arithmetic mean of the lower low water heights of a mixed tide observed over a specific 19-year Metonic cycle (the National Tidal Datum Epoch). Only the lower low water of each pair of waters of a tidal day is included in the mean.

MERISTIC-- Refers to the study of countable measurements, particularly counts of features such as vertebrae, fin rays, and scale rows. These are used in population comparisons and classification.

MESOHALINE-- Water with a salt concentration of 5-18 ppt.

MESOPELAGIC-- The open ocean zone from about t50-t,000 m where light penetration drops rapidly and ceases.

METAMORPHOSIS-- The process of changing from one body form to another distinctly different form during maturation in indirect development (e.g.,) tadpole changing to a frog). See EMBRYONIC DEVELOPMENT.

METRIC TON -- A unit of mass or weight equal to 2,204.6 lbs.

MIGRATION-- A back and forth movement by a population or subpopulation at regular intervals. Vertical migrations in the water column may be daily or seasonal within the same area. Depth migrations between deeper and shallower bottomed areas are usually seasonal and related to breeding. Many marine birds and mammals have seasonal latitudinal migrations also associated with breeding. See EMIGRATION, IMMIGRATION, RANGE, and RECRUITMENT.

MILT -- The seminal fluid and sperm of fish.

MOLT -- The general process of shedding and regrowing an outer covering at periodic intervals. Crustaceans and other arthropods molt their exoskeletons, grow rapidly, and produce larger exoskeletons. Most reptiles, birds, and mammals respectively molt skin, feathers, or fur.

APPENDIX C. --Continued.

MONOECIOUS-- See HERMAPHRODITIC.

MONOPHYLETIC-- Two or more groups (taxa) of organisms derived from a common ancestor.

MORPHOLOGY-- The appearance, form, and structure of organisms.

MORPHOMETRICS-- The study of comparative morphological measurements.

MORTALITY -- The proportion of deaths associated with a population or community of organisms caused by a variety of sources, including predation, disease, environmental conditions, etc.

MOTILE -- Capable of or exhibiting movement or locomotion.

MUTUALISM -- A type of interaction between populations of two species in which all or both derive benefit. Some authorities consider true mutualism to be obligatory for both species, while mutually beneficial relationships that are not essential for either species are classified as protocooperative (e.g., the blacksmith cleaning fish eats externally attached organisms from the sea bass).

NACREOUS MATERIAL -- A calcarious secretion in the inner surface of the mantle of many molluscs. Foreign particles lodging between the inner shell surface and the mantle are covered by nacre, sometimes forming pearls.

NANNOPLANKTON-- Planktonic organisms smaller than 40 microns in diameter.

NATAL -- Relates to birth or hatching.

NEKTONIC -- Animals that are strong swimmers, live above the substrate in the water column, and can move independently of currents.

NEMERTEA -- A phylum of unsegmented, elongate marine worms having no body cavity, a protrusible proboscis, and living mostly in coastal mud or sand; nemerteans.

NERITIC -- Refers to the pelagic zone from the mean low tide level to the edge of the continental shelf. See INNER SHELF, LITTORAL, and OCEANIC ZONES.

NEUSTON -- Organisms that live at or on the water surface, often depending on surface tension for support. Like plankton down in the water column, they drift with currents.

NICHE -- The fundamental niche is the full range of abiotic and biotic factors under which a species can live and reproduce. The realized niche is the set of actual conditions under which a species, or a population of a species, exists, largely determined by interactions with other species.

NOCTURNAL-- Relates to night, or animals that are active at night.

OCEANIC ZONES -- The part of the pelagic realm seaward of the edge of a continental shelf. See BATHYPELAGIC, EPIPELAGIC, ABYSSOPELAGIC, MESOPELAGIC, and NERITIC.

APPENDIX C. --Continued.

OLIGOHALINE-- Water with a salt concentration of 0.5 to 5.0 ppt., typical of estuarine conditions.

OMNIVORE -- An animal that eats both plants and animals.

OREGON PROVINCE -- A zoogeographical designation for faunal distributions that, based on minimum temperature requirements, extends from Puget Sound, Washington, to Point Conception, California; Oregonian.

OOCYTES -- The cells in ovaries that mature into eggs.

OVIGEROUS -- The condition of being ready to lay mature eggs.

OVIPAROUS -- Animals whose eggs develop and hatch outside the body of the mother. See OVOVIVIPAROUS and VIVIPAROUS.

OVIPOSITION-- The process of placing eggs on or in specific places as opposed to the practice of randomly dropping or broadcasting them.

OVOVIVIPAROUS-- The condition where eggs are fertilized, developed, and hatched in the mother's body, but receive no nourishment from the mother. See OVIPAROUS and VIVIPAROUS.

PALP -- A jointed sensory organ attached to the head appendages of various arthropods; a fleshy sensory organ in the buccal cavity of various invertebrates.

PARASITISM-- An interspecific interaction where members of one species (parasite) feed on, or use the metabolic mechanisms of, the second (host). Unlike predators, parasites usually do not kill their hosts, although hosts may later die from secondary causes that are related to a weakened condition brought about by the interaction. Parasitism may also be fatal when high parasite density develops. Population effects are the same as in predation.

PARR-- Juvenile salmon and trout that have a series of dark, vertical bars on their sides and are only a few inches long.

PATHOGEN-- A microorganism or virus that can cause death.

PELAGIC-- Refers to the realm of ocean water above the benthic realm (bottom), or to organisms living in the water column in oceanic or neritic zones.

PELAGIVORE-- A carnivore that feeds in the water column.

PHYLOGENY-- Refers to evolutionary relationships and lines of descent.

PHYTOPLANKTON-- Microscopic plants and plant-like protists (algae) of the epipelagic and neritic zones that are the base of offshore food webs. They drift with currents, but usually have some ability to control their level in the water column. See ALGAE and DIATOMS.

APPENDIX C. --Continued.

PISCIVOROUS-- A carnivorous animal that eats fish.

PLANKTIVOROUS-- An animal that eats phytoplankton and/or zooplankton.

PLANKTON -- See PHYTOPLANKTON and ZOOPLANKTON.

POLYCHAETE -- A group of segmented, mostly marine, annelid worms bearing bristled, fleshy appendages on most segments.

POLYHALINE -- Water with a salt concentration between 18 and 30 ppt.

POPULATION -- A group of individuals of the same species occupying a defined area during a given time. Environmental barriers may divide the population into local breeding units (demes) with restricted immigration and interbreeding between the localized units. See SPECIES, SUBSPECIES, and SUBPOPULATION.

PPT -- Parts per thousand.

PRECOCIAL-- Developmentally advanced.

PREDATION -- An interspecific interaction where an animal species (predator) feeds on another animal or plant species (prey) while the prey are alive or after killing them. The relationship tends to be positive (increasing) for the predator population and negative (decreasing) for the prey population. See PARASITISM, SYMBIOTIC, CARNIVORE, and TROPHIC LEVEL.

PRODUCTION-- Gross primary production is the amount of light energy converted to chemical energy in organic compounds by autotrophs like algae. The amount left after respiration is net primary production and is usually expressed as biomass or calories/unit area/unit time. Net production for herbivores and carnivores is based on the same concept, except that chemical energy from food, not light, is used and partially stored for life processes. Efficiency of energy transfers between trophic levels is seldom greater than 10%; therefore, organisms at high trophic levels have only a fraction of the energy available to them that was stored in plant biomass. After respiration loss, net production goes into growth and reproduction, or is passed to the next trophic level (e.g., human harvest of commercial fish). See FOOD WEB and TROPHIC LEVEL.

PROKARYOTIC-- Refers to cells that have nuclear bodies but lack chromosomes, nucleoli, and nuclear membranes.

PROTANDRY-- A type of hermaphroditism in which the same gonads in an individual produce eggs and sperm at different times during its lifespan. This individual is then regarded as a different sex. The condition is fairly common among fish and invertebrates.

PROTISTAN-- A varied unicellular organism of the general taxonomic category Protista, which possesses characteristics from such groups as the algae, fungi, and protozoans.

APPENDIX C. --Continued.

PROTOZOA-- A varied group of either free-living or parasitic unicellular flagellate and amoeboid organisms.

PYCNOCLINE-- A graded or gradual change in water density with depth.

RADULA-- A toothed belt in the buccal cavity of most molluscs that is used to scrape food particles from a surface, or modified otherwise to serve a variety of feeding habits.

RANGE -- (1) The geographic range is the entire area bounded by the extremes of locations where a species is known to occur or to have occurred (historical range). The range of a species may be continuous, or it may have unoccupied gaps between populations (discontinuous distribution). (2) Some populations, or the entire species, may have different seasonal ranges. These may be overlapping, or they may be widely separated with intervening areas that are at most briefly occupied during passage on relatively narrow migration routes. (3) Home range refers to the local area that an individual or group uses for a long period or life. See DISTRIBUTION and TERRITORY.

RECRUITMENT-- The addition of new members to a population or stock through maturation of juveniles and immigration.

RED TIDE -- A reddish discoloration of sea waters, caused by a bloom in populations of red protozoan flagellates. A large accumulation of metabolic by-products from these organisms is toxic to fish and other marine life and is responsible for mortality.

REDD -- A depression in gravel dug by female salmon and trout where spawning is completed. The eggs are then covered with gravel by sweeping movements of the tail.

REPRODUCTIVE POTENTIAL -- The total offspring possible for a female of a given species if she lives to the maximum reproductive age. This is found by multiplying the number of possible reproductive periods by the average number of eggs or offspring produced by females of each age class. This potential is seldom realized, but this and the age of first reproduction, or generation time, determine the maximum rate of population increase under ideal conditions.

RHEOTAXIS-- A response movement by an animal toward or away from stimulation by a water current.

RIVERINE-- Relates to activity or presence in streams.

ROE -- The egg mass of fish within the ovarian membrane.

SAN DIEGO PROVINCE -- A zoogeographical designation for faunal distributions that, based on minimum temperature requirements, extends from Point Conception, California, to Magdalena Bay, Baja California Sur; San Diegan.

SCAVENGER-- Any animal that feeds on dead animals or scraps and remains of animals killed by other predators. See DECOMPOSER and DETRITIVORE.

APPENDIX C. --Continued.

SEAMOUNT-- An undersea mountain whose top is below sea level, in contrast to an island.

SEDENTARY-- Regards animals that remain in a restricted area, or those that have little ability to move. See SESSILE.

SEMELPAROUS-- Refers to animals that have a single reproductive period during their lifespan.

SESSILE - Refers to organisms that are attached to the substrate or are nonmotile. See SEDENTARY.

SHOAL -- (1) A sand bar in a body of water that is exposed at low tide. (2) An area of shallow water. (3) A group of fish (school). (4) As a verb, to collect in a crowd, group, or school.

SIPHONS -- Tubes of clams and other bivalves that are used to bring water with food items and oxygen to the gills and back to the water column above the burrows.

SLOUGH -- A shallow mudflat that is exposed at low tide, often with a stream passing through. Sloughs often border estuaries.

SMOLT -- Juvenile salmon or anadromous trout in the process of adapting and moving to the ocean.

SPAT -- Juvenile bivalve molluscs which settle from the water to the substrate to begin adult life.

SPAWN -- With fish, to lay eggs. This usually occurs during mating, but may occur later in species with internal fertilization; the released eggs.

SPECIES -- One or more populations whose members interbreed when in contact and produce fertile offspring, and have the potential to interbreed when not currently in contact. See POPULATION, SUBPOPULATION, and SUBSPECIES.

SPERMATOPHORE-- A gelatinous packet containing sperm that is produced by some male animals in a number of taxonomic groups.

SPIROCHAETE-- A spiral-shaped, non-flagellated bacteria of the order Spirochaetales. This varied group can be free-living, parasitic, or disease-causing.

SPIT -- A long, narrow sand bar partially connected to the shore. See SHOAL.

SPOROCYST -- A simple larval stage of parasitic trematode worms. Contact with the host causes a metamorphosis from an earlier stage to this one.

STENOHALINE-- A narrow tolerance range for salt concentration, in contrast to euryhaline.

STIPE-- A thickened, stemlike structure in kelps bearing other structures such as blades; basal portion of the thallus or plant body of alga.

APPENDIX C. --Continued.

STOCK -- A mature breeding population that is, or could be, exploited by man. See POPULATION and SUBPOPULATION.

SUBLITTORAL-- Refers to the benthic zone along the coast that is not uncovered by mean low tides and that extends to depths of about 200 m.

SUBPOPULATION -- A breeding unit (deme) of a defined population. These may differ little genetically, and are not taxonomic units. See SUBSPECIES. Subpopulations may intergrade with some interbreeding, or they may occupy a common seasonal range prior to the mating season. Populations from the same breeding area may form subpopulations based on hatching year in salmonids and others when each year-class breeds only once at a specific age. See STOCK and POPULATION.

SUBSPECIES-- A taxonomic class assigned to populations and/or subpopulations when interbreeding (gene flow) with one or more other subspecies is limited, and there are significant differences in some combination of characteristics between subspecies (e.g., appearance, anatomy, ecology, physiology, and behavior). When successful interbreeding does not occur when the groups are in contact under natural conditions, reproductive isolation is complete, and the groups are considered distinct species. Classification of such groups that are not naturally in contact is based on the comparative study and judgement of phylogenists. A second epithet for each subspecies is added to the binomial for the species (e.g., Sebastes alutus alutus and Sebastes alutus paucispinosus). See SPECIES, POPULATION, and SUBPOPULATION.

SUBTIDAL-- See SUBLITTORAL.

SUPRALITTORAL-- Refers to the splash zone of land adjacent to the sea that is above the mean high tide level.

SUSPENSION FEEDER -- An animal that feeds on minute organisms and organic debris that is suspended in the water, directly or by filtration.

SYMBIOTIC-- Refers to a relationship between two different species that may be positive, negative, or neutral in its effects on the populations of each. See COMPETITION, MUTUALISM, PARASITISM, and PREDATION.

TAXONOMY-- A system of arranging animals and plants into related groups based on common features (e.g., structure, embryology, biochemistry).

TEMPERATE REGION -- Oceanic waters between the 13°C winter isotherm and the 20°C winter isotherm. The temperate region of the neritic zone on the Pacific coast of North America extends from Point Conception, California, to Magdalena Bay, Baja California Sur.

TEMPORAL -- Used regarding activities, developmental stages, and distributions as they relate to daily, seasonal, or geologic time periods.

TEST -- A rigid calcareous exoskeleton found in the echinoderm class Echinoidea (e.g., sea urchins, sand dollars).

APPENDIX C. --Continued.

TERRITORY -- An area. occupied and used by an individual, pair, or larger social group, and from which other individuals or groups of the species are excluded, often with the aid of auditory, olfactory, and visual signals as well as threat displays and outright combat.

THERMOCLINE -- A relatively narrow layer of water where temperature decreases rapidly with depth. This layer separates warmer upper water from colder lower water. Little water or solute exchange occurs across the thermocline while it is maintained by solar heating of the upper layers.

TREMATODE -- A large class of parasitic flatworms with one or more muscular, external suckers, such as a fluke.

TRIPLOIDY -- The occurrence of three times the haploid number of chromosomes. When genetically engineered, randomly occurring traits may be selected for commercial applications. For example, Pacific oyster experiences a degradation in the quality of the flesh associated with spawning. Non-reproducing, triploid cultures avoid this seasonal problem.

TROCHOPHORE-- A molluscan larval stage (except in Cephalopoda) following gastrulation (embryonic stage characterized by the development of a simple gut). It is commonly ciliated, biconically shaped, and free-swimming and establishes an evolutionary link between annelids and molluscs in that both groups display important similarities during this life stage.

TROPHIC LEVEL -- The level from which an organism gets its energy, based on degree of removal from the sun. At the first level are autotrophs or producers (e.g., kelp and diatoms); second level are herbivores (e.g., copepods and snails); third level and above are carnivores (e.g., salmon and seals). Omnivores feed at the second and at least one higher level, and many animals feed at several levels. Decomposers and detritivores feed at all trophic levels. See FOOD WEB and PRODUCTION.

TROPICAL REGION -- Oceanic waters between the 20°C winter isotherms in the southern and northern hemispheres. Tropical neritic waters along the west coasts of North and South America extend from the southern tip of Baja California, Mexico, to about lat. 5°s. along the coast of Peru.

TURBELLARIA-- A class of mostly aquatic, non-parasitic flatworms appearing leaf-shaped and covered with cilia; turbellarian.

UPWELLING-- The process where prevailing seasonal winds create surface currents that move cold water with organic nutrients from ocean depths and sediments back to the euphotic or epipelagic zone. This breaks down the thermocline and allows increased production by algae, resulting in very valuable fisheries.

VELIGER -- A developmental stage common in molluscs, which forms after the trochophore larva. This is a stage of considerable differentiation when adult features such as the shell and foot become apparent.

VIVIPAROUS -- Eggs are retained in the reproductive system and the young are released live.

APPENDIX C. --Continued.

WATER COLUMN -- The water from the surface to the bottom at a given point.

YEAR-CLASS-- All animals in a population hatched or born in the same year at about the same time also known as a cohort. Strong year-classes result when there is a high early survival rate, and the reverse is true for weak classes. The effects on population size and structure may persist for years in species with longer lifespans. Variation in strength often affects the fisheries. See DISTRIBUTION and STOCK.

ZOEA-- One of several in a series of early larval stages of various marine crabs, and shrimp displaying many appendages and long dorsal and anterior spines.

ZOOPLANKTON -- Animal members of the plankton. Most range from microscopic to about an inch in length. They feed on phytoplankton and each other. Some groups included are protozoa, jellyfish, comb jellies, arrowworms, lower chordates, copepods, water fleas, krill, and the larvae of many fish and invertebrates that are not planktonic as adults. They have little or no ability to swim against currents and drift passively with the currents, primarily in the upper or epipelagic zone.